NASA-CR- 152455

REDUCTION AND ANALYSIS OF DATA COLLECTED DURING THE
ELECTROMAGNETIC TORNADO EXPERIMENT

FINAL REPORT

NASA Contract NAS5-22489

TECHNO-SCIENCES INC.

1712 South Harbor Lane

Annapolis, Md. 21401

TSI Report No. 76112
July 1976

Prepared for:

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
76112		

4. Title and Subtitle	5. Report Date
REDUCTION AND ANALYSIS OF DATA COLLECTED DURING THE ELECTROMAGNETIC TORNADO EXPERIMENT	July 1976
	6. Performing Organization Code
7. Author(s) L. D. Davisson and J. B. Davisson	8. Performing Organization Report No. 76112
9. Performing Organization Name and Address Techno-Sciences, Inc 1712 South Harbor Lane Annapolis, Maryland 21401	10. Work Unit No.
	11. Contract or Grant No. NAS5-22489
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Goddard Space Flight Center Greenbelt, Maryland 20771	13. Type of Report and Period Covered Type III Final July 1975-June 1976
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This report reviews the work performed under NASA Contract NAS5-22489. The work completed included the strip chart recording of various tornado data, the development and implementation of computer programs for the digitization and analysis of tornado data, the development of data reduction techniques for short pulse radar data, and the simulation of short pulse radar returns from the sea surface by computer models.

17. Key Words Suggested by Author	18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price

PREFACE

The purpose of this contract was to provide data processing and analysis in support of two GSFC programs: tornado detection by analysis of radio frequency interference in various frequency bands and sea state determination from short pulse radar measurements. During the contract period, the contract objectives were completed through various data reduction techniques. Strip chart recordings were made of the analog tapes collected during the tornado collection exercise. These were used for preliminary analysis and as a guide for the selection of the most interesting data for digitization and further analysis using digital computer data reduction techniques. Computer programs were developed for this digitization and analysis. Other computer programs were developed and improved for the analysis of the short pulse radar data. Finally, computer simulations were developed for the short pulse radar returns using Monte Carlo methods on a two-dimensional electromagnetic propagation model. Comparisons of the modelled data with measured data indicated a high degree of similarity between the two sources.

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I. Introduction

The data supplied by GSFC for analysis and data reduction consist of 14 track analog tornado tapes and 9 track, 800 cpi digital short pulse radar tapes. The tornado tapes were generated by another contractor to GSFC under GSFC direction and contain the information shown in table I.1. The recordings cover 4 HF and VHF frequency bands with vertical and horizontal polarizations and with linear and logarithmic scales. In addition the outputs from 2 different lightning stroke detectors were recorded. Recording speeds of 30 ips and 60 ips were used. A data base of over 50 tapes was used by Techno-Sciences for the analysis and reduction.

Techno-Sciences provided analog strip charts of all available tapes on GSFC supplied equipment in coordination with the contract technical officer during the contract period. A complete log of this processing is included with this report in table I.2. Because the strip chart recorder has only 7 useable channels, only half of the tracks on each tape could be done in each pass. However, it was found that 7 selected tracks had most of the interesting information anyway.

After the completion of the strip chart recording task, digital computer programs were developed for the digitization of selected data portions from an analog tape recorder playback. These portions were selected under the direction of the GSFC technical officer. The digitized tapes then were displayed on various time scales to reveal the detailed structure of the lightning waveforms. An analysis program was developed to compute interpulse time histograms and amplitude distributions.

The short pulse radar data was recorded during the JONSWAP exercise by GSFC on 9 track 800 cpi digital tapes using programs developed by Techno-Sciences. 23 tapes were generated under a variety of sea conditions and equipment configurations. Techno-Sciences developed analysis techniques for the recorded data including histogram, spectral density and interpeak analysis techniques.

An important tool in the difficult task of determining sea state conditions from short pulse radar data is the use of simulated data. Data generated by simulations is highly controlled so that it is possible to find and evaluate estimation methods without uncertainty as to the true value of the quantity to be estimated. Techno-Sciences devloped a 2 dimensional computer simulation during the contract period. The modelled data has a high degree of correlation with the measured data in appearance.

TABLE I.1

TORNADO ANALOG TAPE TRACK ASSIGNMENTS

Track	Mode	Assignment
1	Direct	V-3 Mhz Lin
2	Direct	V-3 Mhz Log
3	Direct	V-30 Mhz Lin
4	Direct	V-30 Mhz Log
5	Direct	V-VHF 139 Mhz Lin
6	Direct	V-UHF 295 Mhz Lin
7	Direct	H - VHF 139 Mhz Lin
8	Direct	H - UHF 295 Mhz Lin
9	FM	10 Khz Time Mark or 100 Khz at 60 ips
10	FM	WWVB BCD Time Code
11	Direct	V-Lightning Stroke Det-Lin
12	Direct	V-Lightning Stroke Det-Log
13	FM	Taylor Tornado Det-Far
14	FM	Taylor Tornado Det-Near

TABLE I.2

TORNADO DETECTION ANALOG TAPE PROCESSING LOG

Date Processed	Time	Tape Designation	Record Speed	Playback Speed	Strip Chart Speed	Tracks	Operators	Comments
9/17/75	0920	8/5/75:1647	60 ips	60 ips	.5 cm/sec	1 - 7	LD, JB	Very active
9/17/75	1015	8/5/75:1647	60 ips	60 ips	.5 cm/sec	8 -14	LD, JB	1st minute sporadic Tr 14 inactive Timing pulses in tr 13 approx 8 sec period
9/17/75	1115	8/5/75:1702	30 ips	30 ips	.5 cm/sec	8 -14	LD, JB	Tr 13&14 as above, good BCD time code on tr 10
9/17/75	1155	8/5/75:1827	30 ips	30 ips	.5 cm/sec	8 -14	LD,JB,DL	Discontinued because of doubt about track assignments on tape. Printout not kept.
9/17/75	1225	8/5/75:1827	30 ips	30 ips	.5 cm/sec	1 - 7	LD,JB	Recorder gain low on first half of output. Strip recorder out at end of tape.
9/17/75	1600	6/29/75:#5	60 ips	60 ips	.5 cm/sec	1,3,5,6 8,11,13	LD,JB	Quiet data. Tr 13 blank
9/17/75	1625	6/29/75:#3	60 ips	60 ips	.5 cm/sec	1,3,5,6 8,11,13		Quiet data. Tr 13 blank.
9/17/75	1645	8/5/75:1909	30 ips	30 ips	.5 cm/sec	1,3,5,6 8,11,13		Very active data.
9/19/75	1430	8/26/75:1630 #3	60 ips	120 ips	1 cm/sec	1,3,5,6 8,11,13	JB	Very active, low background noise Tr 13 blank
9/19/75	1455	8/26/75:1645 #4	60 ips	120 ips	1 cm/sec	1,3,5,6 8,11,13	JB	Very active, low background noise Tr 13 blank

TORNADO DETECTION ANALOG PROCESSING LOG

Date Processed	Time	Tape Designation	Record Speed	Playback Speed	Strip Chart Speed	Tracks	Operators	Comments
9/19/75	1510	8/26/75 # 5	60 ips	120 ips	1 cm/sec	1,3,5,6, 8,11,13	JB	Very active Sferics Low background noise Tr 13 blank
9/22/75	1230	8/26/75 # 2	30 ips	120 ips	2 cm/sec	1,3,5,6, 8,11,13	JB,LD	Tr 5 appears to limit on all of the 8/26/75 tapes. Tr 11 has a periodic waveform & Tr 13 has occasional spikes, but is otherwise inactive. Trs. 1,3,5,6,8 all very active sferics.
9/22/75	1300	8/26/75 #1	60 ips	120 ips	1 cm/sec	1,3,5,6 8,11,13	JB,LD	see above
9/22/75	1325	8/5/75:1853 # 1	60 ips	120 ips	1 cm/sec	1,3,5,6, 8,11,13	JB,LD	Tr 13 active near end Tr 11 has periodic pattern. Trs 1,3,5,6, 8 active
9/22/75	1342	8/19/75:1722 # 1	60 ips	120 ips	1 cm/sec	1,3,5,6 8,11,13	JB	
9/22/75 9/23/75 9/23/75 9/23/75	1400 0900 0935 1100	7/8/75:# 1 7/8/75:# 2 7/8/75:# 3 7/8/75:# 4	60 ips	120 ips	1 cm/sec	1,3,5,6 8,11,13	JB	Moderate actvity on all channels.Taylor's detector(Tr 13) working:spikes emitted at lightning bursts. Lightning stroke detector(tr 11) puts out noise&timing only

TORNADO DETECTION ANALOG TAPE PROCESSING LOG

Date Processed	Time	Tape Designation	Record Speed	Playback Speed	Strip Chart Speed	Tracks	Operators	Comments
9/23/75 9/23/75	1330 1400	6/28/75:#1 6/28/75:#2	30 ips 60 ips	120 ips 120 ips	2 cm/sec 1 cm/sec	1,3,5,6 8,11,13	JB	Not rewound Inactive data Tr 13 not working
9/24/75	0925 1005	6/28/75:#3 6/28/75:#4	30 ips 60 ips	120 ips 120 ips	2 cm/sec 1 cm/sec	1,3,5,6, 8,11,13	LD	Inactive data-almost no signal,tape deck noise only. Timing marks on tr 11, occasional spikes on tr 13.
9/26/75	0855 0930 1030 1100	6/25/75:#1 1656 :#2 :#4 :#3	30 ips 30 ips 30 ips 30 ips	120 ips 120 ips 120 ips 120 ips	2 cm/sec 2 cm/sec 2 cm/sec 2 cm/sec	1,3,5,6 8,11,13	JB	Quiet data. Lightning Stroke Det(tr 11) & Taylor's detector(tr 13) working sporadic-ally at best.
9/26/75	1325 1425 1500 1520 1545	6/29/75:#1 :#2 :#4 :#6 :#7	60 ips 30 ips 30 ips 60 ips 60 ips	120 ips 120 ips 120 ips 120 ips 120 ips	1 cm/sec 2 cm/sec 2 cm/sec 1 cm/sec 1 cm/sec	1,3,5,6 8,11,13	JB	Quiet data. Track 13 has a periodic pulse train.
9/26/75	1620 1640	7/5/75:#1 :#2	30 ips 60 ips	120 ips 120 ips	2 cm/sec 1 cm/sec	1,3,5,6 8,11,13	JB	Low to moderate activity. LS det(tr 11) works sporadically. Tr 13 has a periodic pulse train

TORNADO DETECTION ANALOG TAPE PROCESSING LOG

Date Processed	Time	Tape Designation	Record Speed	Playback Speed	Strip Chart Speed	Tracks	Operators	Comments
9/30/75	1000	8/12/75: 1610 #1	60 ips	120 ips	1 cm/sec	1,3,5,6, 8,11,13	JB	Not good data
	1025	8/12/75: 1624 #2	30 ips	120 ips	2 cm/sec		JB	
9/30/75	1045	8/18/75: 1645 #1	60 ips	120 ips	1 cm/sec	1,3,5,6, 8,11,13	JB	Something on chan. 5 only.
	1055	8/18/75: 1735 #2	30 ips	120 ips	2 cm/sec		JB	
9/30/75	1155	9/12/75: 1547 #2	30 ips	120 ips	2 cm/sec	1,3,5,6, 8,11,13	JB	Disconnected from DC offset board. Works better now.
9/30/75	1205	7/6/75 #1	60 ips	120 ips	1 cm/sec	1,3,5,6, 8,11,13	JB	Good data
9/30/75	1420	9/10/75: 1645 #1	60 ips	120 ips	1 cm/sec	1,3,5,6, 8,11,13	JB	Good data
9/30/75	1435	9/11/75	60 ips	120 ips	1 cm/sec	1,3,5,6, 8,11,13	JB	Very good data
9/30/75	1500	9/10/75: 1700 #2	30 ips	120 ips	2 cm/sec	1,3,5,6, 8,11,13	JB	Small related pattern nothing on chan. 11 & 13.
9/30/74	1510	9/12/75: 1533 #1	60 ips	120 ips	1 cm/sec	1,3,5,6, 8,11,13	JB	Data on all chan. but 13.
	1530	9/12/75: 1625 #3	60 ips	120 ips	1 cm/sec			
	1550	9/12/75: 1640 #4	30 ips	120 ips	2 cm/sec			
	1605	9/12/75: 1710 #5	60 ips	120 ips	1 cm/sec			

TORNADO DETECTION ANALOG TAPE PROCESSING LOG

Date Processed	Time	Tape Designation	Record Speed	Playback Speed	Strip Chart Speed	Tracks	Operators	Comments
9/30/75	1615	7/6/75 #2	60 ips	120 ips	1 cm/sec	1,3,5,6, 8,11,13	JB	Data on all chan. but 13.
10/7/75	900	8/26/75: 1645 #4	60 ips	120 ips	1 cm/sec	1,3,5,6, 8, 11,13	JB	Nothing on chan. 11
10/7/75	920	9/12/75: 1547 #2	30 ips	120 ips	2 cm/sec	1,3,5,6, 8,11, 13	JB	Nothing on chan. 13
10/7/75	1000	6/24/75: #1 noon test	30 ips	120 ips	2 cm/sec	1,3,5,6, 8,11,13	JB	Nothing on chan. 13
	1140	6/24/75 Noon test #2	un-determined	120 ips	2 cm/sec and 1 cm/sec			
	1100	6/24/75 #1 PM flight	30 ips	120 ips	2 cm/sec			
	1120	6/24/75: 1729 #2	30 ips	120 ips	2 cm/sec			
10/7/75	1210	8/12/75: 1624 #2	30 ips	120 ips	2 cm/sec	1,3,5,6, 8,11,13	JB	No data
10/7/75	1230	8/18/75: 1645 #1	60 ips	120 ips	1 cm/sec	1,3,5,6, 8,11,13	JB	Light data
		8/18/75: 1735 #2	30 ips	120 ips	2 cm/sec			
10/21/75	945	8/12/75: 1610 #1	60 ips	120 ips	1 cm/sec	1,3,5,6, 8,11,13	JB	Something on 5 & 11 only.
10/21/75	1000	9/12/75: 1533 #1	60 ips	120 ips	1 cm/sec	1,3,5,6, 8,11,13	JB	Data on all Chan. but 8 and 13.
10/21/75	1020	7/6/75 #1	60 ips	120 ips	1 cm/sec	1,3,5,6, 8,11,13	JB	Data on all chan. but 8 and 13. Not much on 3.

TORNADO DETECTION ANALOG TAPE PROCESSING LOG

Date Processed	Time	Tape Designation	Record Speed	Playback Speed	Strip Chart Speed	Tracks	Operators	Comments
10/21/75	1035	7/6/75 #2	60 ips	120 ips	1 cm/ sec	1,3,5,6, 8,11,13	JB	Data on all chan. but 8 & 13
	1040	7/6/75 #3	30 ips	120 ips	2 cm/sec			Light data in beginning then everything stops half way through.
10/21/75	1300	9/12/75	varies	as designa- ed	.1 cm/sec	1,3,5,6, 8,11,13		5 tapes on one chart with strip chart slowed down to .1 cm/sec

II. Analog Strip Chart Recordings

Table II is a processing log which summarizes the useful analog strip chart recording results by Techno-Sciences on GSFC supplied equipment. In addition to these results, other recordings were made but not kept because of various equipment problems which resulted in invalid or useless data displays. Many of the tapes were found to be very quiet, containing indiscernable signals or noise of a "white" rather than of the desired impulsive nature characterizing lightning discharges. Others, however contained considerable amounts of the desired impulsive noise across all frequencies. A short segment of one of these displays appears in figure II.1.

The data was recorded at a real time (one-sided) bandwidth of 300 khz. As shown in Appendix A, the strip chart recording technique used is physically limited to be able to show only about 20% of the actual bandwidth. Even this could only be achieved at 1-7/8 ips playback speeds and 50 cm/sec strip chart speeds, which would generate unacceptably large amounts of output. Hence, the strip chart recordings can only be viewed as a "quick look" tool. Selected portions of the data must be digitized for processing and display.

As shown in Appendix B, the amount of digital data generated from even a short segment of analog tape is very large. Hence, the segments must be carefully selected. The addition of a timing track may be necessary in this regard as an aid in registration at some point.

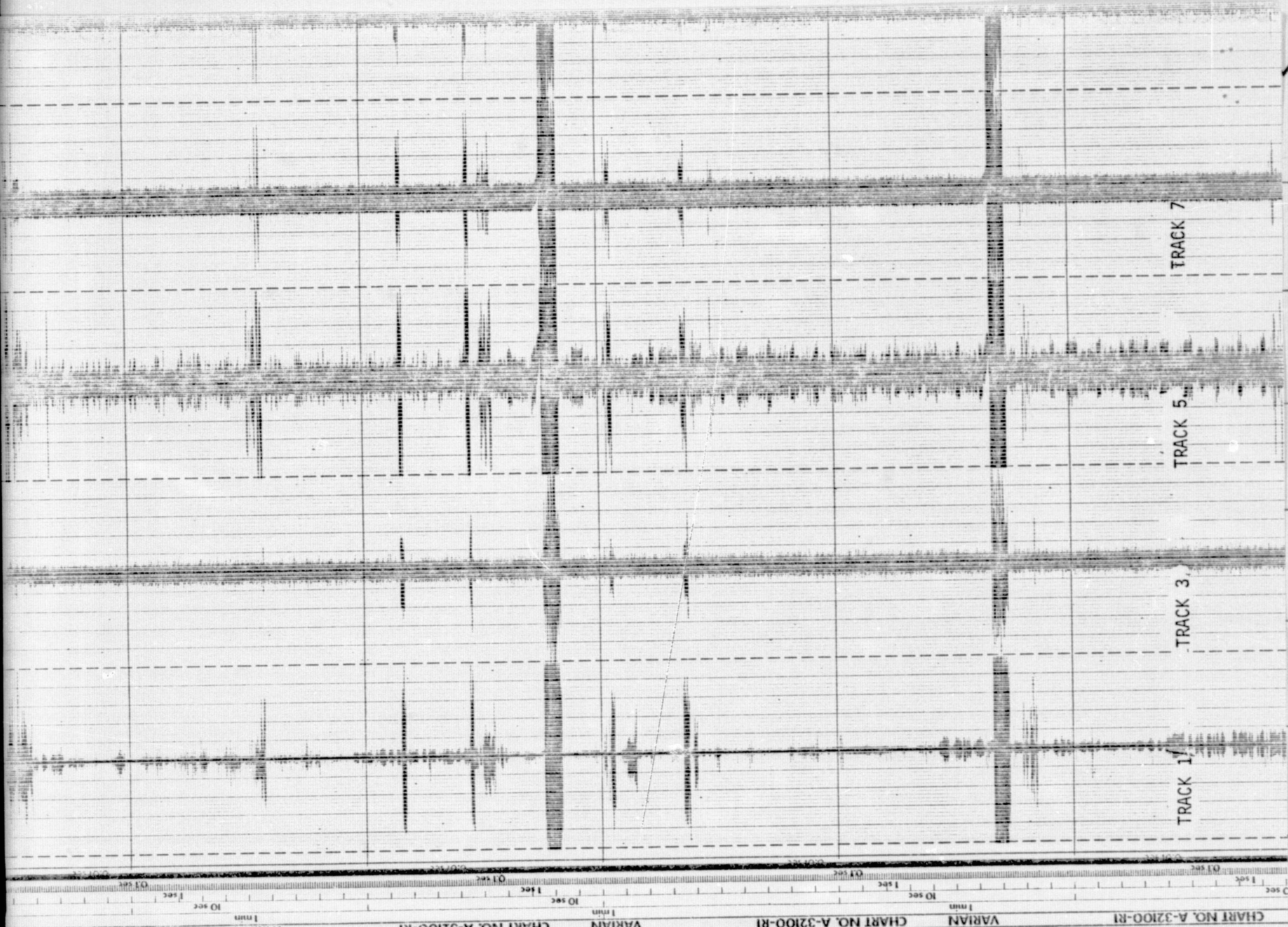

Figure II.1. Sample Strip Chart Recording

III. Tornado Data Digitization

Selected portions of tornado data were digitized by Techno-Sciences in coordination with GSFC. The Ampex PR-2200 tape recorder used in the recording of the data was interfaced to the Interdata Model 5 through an A/D converter which was originally developed for data compression. Computer programs were written by Techno-Sciences for the digitization and recording of the original analog tape data on disk and 9 track digital tape. Data recorded on disk is transferred to tape after the disk pack is full. 15 bit 2's complement samples were recorded. The disk record mode supports a rate of slightly less than 20,000 samples per second. The direct tape record mode supports a rate of slightly less than 10,000 samples per second. Most data has been recorded directly to tape in the interests of conserving operator time and maximizing the data throughput on each record cycle. Each disk pack holds approximately 2.5 megasamples, less than ¼ the storage capacity of a digital tape. Thus, in terms of real time, when operating the analog playback equipment so that the Nyquist rate of 600,000 samples per second is achieved, approximately 20 seconds of real time appear on a digital tape in the direct mode whereas only approximately 5 seconds of real time can be accomodated on disk record pass. Nonetheless, because of the low pass cutoff of the analog tape recorder, it is sometimes desirable to record at the higher rate to disk.

Appendix C contains a listing of the program developed for the digitization of data for disk storage. The program for direct tape storage is similar, but is not given.

IV. Computer Programs for Tornado Digital Data Reduction

Three major computer programs were developed for the analysis and reduction of the digitized tornado data. The goals of the programming effort were to develop the capability of displaying selected data portions and analyzing them for their statistical characteristics. This required the development of an appropriate printer/plotter routine in addition to the formatting, I/O, and analysis routines. Additional effort was expended on programming for joint operation on the Interdata Models 5 and 8/32.

The three programs are called SHOALL, REDUCE, and TORNANAL. The listings of these programs appear in Appendix D. The plotting program, called PLOTIT, appears in Appendix G. Program SHOALL plots out the input data, removing non-data portions (noise-only) from the plot based on an input threshold and time-window. Other program inputs are the number of points to be used in a FFT spectral analysis, the number of tape records (one tape record=12800 samples) to be processed, the real time sampling rate in kilosamples/second, the time between plotted timing lines in milliseconds, and the number of times each sample is to be repeated for possible axis expansion. If the repeats are set equal to 0, no waveform plotting is done. Similarly, if the number of FFT points is set equal to zero, no spectral analysis is done. The output plot starts with a header which is entered by the operator. This is followed by the waveform plotted as a function of time. Everytime a portion of the input is skipped due its detection as noise only, the amount of time skipped is printed out. Upon the completion of the processing of the desired number of records, or

upon the detection of tape abnormal status (normally end of file) on read, the program prints out the magnitude of the average power spectrum, accumulated by the FFT operation over each data portion, and terminates.

Program REDUCE is for quick-look plotting of the digitized tornado data. Inputs are the real time sampling rate and the desired output real time plotting rate. The data is filtered by a simple RC filter with 3 db point at ½ the Nyquist rate to reduce aliasing. The output plot starts with a header which is input by the operator to identify the data, date, etc. and is followed by the plotted data with vertical timing lines every 10 msec in real time. The program terminates upon abnormal tape status (normally end of file).

Program TORNANAL is used to do statistical analyses on the tornado data. An amplitude histogram and a histogram on the time between threshold up-crossings is computed. Inputs to the program are the number of tape records to be processed, the minimum time interval between up-crossings to be counted as a peak event and the up-crossing threshold. Outputs are the input parameters and plots of the histograms on a log scale. Examining the sample printout in appendix D, it is seen that the histogram cdf is approximately linear, indicating an exponential distribution for the interpulse arrivals and hence a Poisson peak occurence model. The amplitude histogram indicates agreement with a Gaussian amplitude model.

The reader is referred to Appendix D for listings of the three main programs and for sample printouts of each program.

V. Data Reduction for the Short Pulse Radar Data

The short pulse radar data is recorded on 800 cpi digital tape. Program ECKPDF was developed for the analysis of this data. The listing of the program and a sample output appears in Appendix E. The program performs amplitude histograms, spectral analyses, and interpulse time histograms. In addition, the average pulse shape across the input data and the shape of each input pulse can be plotted. These pulses appear on a linear scale in time, as they are recorded, and on an estimated linear scale in range and on an estimated linear scale in antenna angle. The necessity for estimation arises from the need for an absolute range and antenna angle calibration on the data at some point in the recorded time record. This estimated point is found by taking the leading edge of the return pulse and assuming that it corresponds to the lower 3 db point of the antenna. The range and angle scales are then determined from this assumed angle and the known aircraft altitude at the time of recording.

The program inputs are the desired header on the output plot, the antenna parameters-pointing angle, beamwidth, and range, the number of pulses to be processed, the record format - documentation size, data record size, and total record size, and the number of pulse points to be used in the reduction. A sample of the program output appears with the listing in Appendix E. The input header is followed by the record recorded on the tape giving the radar operator information. Next appears an amplitude histogram. The non-continuous nature of the histogram in the example is due to a misadjusted A/D converter. Next appear the averaged pulses in time, range, and angle. Following this

is the average pulse power spectrum calculated and accumulated using an FFT routine. Finally, the interpulse time histogram is plotted, the peak of which can be used as an estimate of the average wave spacing. In the example in Appendix E, the last page is a sample of individual pulse printouts, on a linear time, range, and angle basis. These are optional and would normally appear before the average pulses.

VI. Short Pulse Radar Simulation

The problem of sea state estimation from measured short pulse radar information is very complex. Particularly complicating the problem is the lack of accurate "ground truth" data, i.e. the lack of exact knowledge of what an accurate estimate on any particular segment of data is. A good way of removing this problem is to develop computer simulations where the estimated parameters can be accurately known and controlled.

As a part of the contract effort, Techno-Sciences has developed a two-dimensional simulation of the received pulse under a Gaussian surface model. A listing of the program appears in Appendix F along with a sample printout of several pulses. The surface is allowed to consist of any combination of a deterministic sinusoidal component and a Gaussian component with a Pierce-Moskowitz spectrum under operator control. In each case, the period and amplitude is variable. The random portion is generated using an FFT on randomly generated frequency components whose variances are porportional to the Pierce-Moskowitz spectrum at each frequency. The simulation of the pulse return is based on equation (4) of Spectrum of Power Scattered by a Short Pulse From a Stochastic Surface, by David Levine, NASA report X-952-74-299, August 1974. The specular reflection points are found by interpolation between samples of the derivative of the surface where it goes through zero.

It has been found that the simulated results agree well with the measured data.

VII. New Technology

There are no reportable new technology items resulting from the work under this contract. The following review activities were performed to determine any reportable items:

1. The key technological concepts and ideas studied under the contract were identified. These consisted of the methods of analysis of tornado and short pulse radar data. The extent to which these ideas represented new techniques as versus an application of known techniques was reviewed.

2. A review of appropriate published literature to determine the uniqueness of the ideas developed under the contract was performed.

3. A meeting with the technical officer to discuss the results of the contract study effort and points (1) and (2) in connection with efforts performed at GSFC and under contract with other contractors was held.

As a result of the review activities, it was concluded that there were no ideas, discoveries, or improvements or reportable items which were first conceived or reduced to practice under the contract.

Appendix A

Strip Chart Recorder Display Limitations

The Varian strip chart recorder used for the processing of the analog tape recordings under this contract is limited in usefulness by sampling theorem considerations presented in Appendix A. The plotting density of the strip chart recorder is 200 points per inch, which by the sampling theorem allows for a maximum frequency resolution of a waveform of 100 cycles per inch. The maximum strip chart speed is 50 cm/sec or approximately 20 inches/sec. Thus the maximum frequency content of a signal which can be resolved is approximately 2000 hz.

At the recorded speed, the anlog tapes have frequencies up to 300 khz . The maximum record speed used was 60 ips. At a minimum playback speed of 1-7/8 ips, the highest frequency present is then $300/32 \approx 10$ khz or 5 times the strip chart recorder's frequency resolving capability.

Thus digital methods must be used to accurately represent and display the analog tape data. From the preceding considerations it is seen that a minimum sampling rate of 20,000 samples per second must be used. Higher sampling rates are desirable to avoid analog tape flutter/wow problems at 1-7/8 ips by running higher playback (and hence higher sampling) speeds.

Appendix B

Digital Tape Limitations

Based on the sampling rate considerations presented in Appendices A and B, it can be easily shown that great selectivity must be exercized in choosing the data to be digitized for display/ analysis. Each of the 14 300 khz analog tape tracks requires 600,000 samples per second in real time or, at a recording speed of 60 ips, 10,000 samples per inch of analog tape per channel for a total of 140,000 samples per inch for all channels. Assuming 8 bit samples and continuous recording (no record gaps), a 2400 ft. 800 bpi digital tape can hold only (2400 x 12 x 800)/140,000 = 165 inches of analog tape or less than 3 seconds of real time sampled data. Hence the channels chosen for sampling and the actual segments of time should be carefully chosen for maximum information content.

```
[redacted]        F1 TØ DISK UNDER SVC 1 11/75                                    PAGE    1

                      * ØPT LAB=F1TØDK
                      * PRØGRAM TØ INPUT FRØM X'20' A/D
                      * ØN SELCH X'F1' AND ØUTPUT
                      * THRØUGH SVC 1 TØ BRYANT IN ØNE
                      * CYLINDER CHUNKS ØN THE X'FO' SELCH
                      * SECTØR CØUNT AND BUFF BEING FILLED
                      * ARE DISPLAYED ØN D.P. PRØGRAM QUITS
                      * ØN ANY INTERRUPT ØTHER THAN X'F1' DEV
                      * WITH X'14' STATUS (CLØCKED MØDE-EXA)
                      * INCLUDING TTY. NØRMAL TERMINATIØN IS
                      * THEN WHEN DISK IS FULL. DIRECT
                      * SVC TØ DISK IS USED(I.E. RANDØM ACCESS
                      * TØ LU F).
                      * CØNTAINS A WRITE TØ TAPE PRØGRAM ALSØ.
                      *
                      * LDD 11/21/75
                      *
0000                  RO       EQU   0
0001                  R1       EQU   1
0002                  AD       EQU   2
0003                  CØUNT    EQU   3
0004                  SLCH     EQU   4
0005                  RLØW1    EQU   5
0006                  RHIGH1   EQU   6
0007                  RLØW2    EQU   7
0008                  RHIGH2   EQU   8
0009                  READGØ   EQU   9
000A                  RSTØP    EQU   10
000B                  R11      EQU   11
000C                  R12      EQU   12
000D                  R13      EQU   13
000E                  R14      EQU   14
000F                  R15      EQU   15
0000R E110            STAR     SVC   1.BLANK          BLANK DISPLAY
      01D4R
0004R E110                     SVC   1.REWDSK         REWIND DISK TØ SEC 0
      0182R
0008R E120                     SVC   2.SECMES         SEND SECTØRS MESS
      018ER
000CR E110                     SVC   1.GETSEC         GET THEM
      01A4R
0010R E120                     SVC   2.PACK           PACK INTØ RO
      01ACR
0014R 4000                     STH   RO.SECTRS        SAVE
      01C4R
0018R D100                     LM    0.BREGS          GET REGS
      020CR
001CR 48B0                     LH    R11.X'46'        SAVE USUAL RETURN
      0046
0020R 40B0                     STH   R11.SAV
      020AR
0024R 95B0                     EPSR  R11.RO           GØ NØN-INT
0026R DE20                     ØC    AD.CMD           SEND GØ.SINGLE SAMF.ENABLE
      01E1R
002AR 9B21                     RDR   AD.R1            READ ØNE IN
002CR 9F01            CLR      AIR   RO.R1            CLEAR PENDING
002ER 0800                     LHR   RO.RO
0030R 2032                     BNZS  CLR
0032R 950B                     EPSR  RO.R11           GØ INT AGAIN
0034R 9E4A                     ØCR   SLCH.RSTØP
0036R 9A47                     WDR   SLCH.RLØW2
0038R 9A48                     WDR   SLCH.RHIGH2
003AR 9E49                     ØCR   SLCH.READGØ      GØ SELCH
003CR DE20                     ØC    AD.CLKAD         GØ CLØCKED A/D. ARMED
      01DFR
0040R 4030                     STH   CØUNT.WRIT2+8    SET 0 SECTØR
      0208R
0044R CA70                     AHI   RLØW2.10         FIRST SAMPS WILL BE FRØM RDR NØW
      000A
0048R C8F0                     LHI   R15.SET1         PØINT TØ SET1
      0058R
004CR 40F0                     STH   R15.X'46'        ØN INTERRUPT
      0046
0050R E110                     SVC   1.SHØW2          SHØW WAIT
      01E8R
0054R C200                     LPSW  WAIT
      00B0R
0058R 9B2B            SET1     RDR   AD.R11           GET 1 SAMP
005AR 9F01                     AIR   RO.R1            ACK INT
005CR 9B2C                     RDR   AD.R12           READ IN ØNE
005ER 9E4A                     ØCR   SLCH.RSTØP       STØP SELCH
0060R 9B2D                     RDR   AD.R13           READ ANØTHER
0062R 9A45                     WDR   SLCH.RLØW1       SEND LØW A(LØW1)
0064R 9B2E                     RDR   AD.R14           READ ØNE MØRE
0066R 9A46                     WDR   SLCH.RHIGH1      SEND A(BUFF2) HIGH
0068R 9B2F                     RDR   AD.R15
006AR 9E43                     ØCR   SLCH.READGØ      GØ SELCH
006CR 4530                     CLH   CØUNT.SECTRS     SEE IF DØNE
      01C4R
0070R 4380                     BNL   TØTAPE           IF SØ.GØ TØ TAPE
      0132R
0074R CA30                     AHI   CØUNT.NUMSEC     INCR SEC PTR
      0064
0078R 4030                     STH   CØUNT.WRIT1+8    & SET FØR NEXT BLØCK
      01FER
007CR 4030                     STH   CØUNT.SH01       & DISPLAY
      01EER
0080R D0B0                     STM   R11.LØW1         SET FIRST SAMPS
```

```
      0172R
0148R E110            SVC   1,RDDSK         READ BLK IN
      0170R
014CR 4810            LH    R1,RDDSK+2      CK STAT
      0172R
0150R 4230            BNE   ABØRT3
      0102R
0154R E110            SVC   1,WRTTP         WRITE TØ TAPE
      017AR
0158R 4810            LH    R1,WRTTP+2      CK STAT
      017CR
015CR 4230            BNE   ABØRT2
      010ER
0160R 4530            CLH   CØUNT,SECTRS    SEE IF DØNE
      01C4R
0164R 4380            BNL   QUIT
      012AR
0168R CA30            AHI   CØUNT,NUMSEC    INCR SEC CØUNT
      0064
016CR 4300            B     LUP             DØ MØRE
      0144R
0170R 5C0F    RDDSK   DC    X'5C0F',0,LØW1,HIGH1,0
      0000
      0222R
      6621R
      0000
017AR 3802    WRTTP   DC    X'3802',0,LØW1,HIGH1
      0000
      0222R
      6621R
0182R C000    REWDSK  DC    X'C000',0
      0000
0186R 0006    UNPAK   DC    6,MESS+4
      01CAR
018AR 0006    UNPAK2  DC    6,MESS+10
      01D0R
018ER 0007    SECMES  DC    7,18,C'ENTER SECTØRS(HEX)'
      0012
      454E
      5445
      5220
      5345
      4354
      4F52
      5328
      4845
      5829
01A4R 4800    GETSEC  DC    X'4800',0,LØW1,LØW1+3
      0000
      0222R
      0225R
01ACR 0008    PACK    DC    8,LØW1
      0222R
01B0R 0001    PAWS    DC    1
01B2R 0007    TAPMES  DC    7,10,C'READY LU 2'
      000A
      5245
      4144
      5920
      4C55
      2032
01C0R 8802    EØF     DC    X'8802',0
      0000
01C4R         SECTRS  DS    2
01C6R 0007    MESS    DC    7,10,C'XXXX  XXXX'
      000A
      5858
      5858
      2020
      5858
      5858
01D4R 2811    BLANK   DC    X'2811',0,BL
      0000
      01DAR
01DAR 0000    BL      DC    0,0
      0000
01DER 0070    CLK     DC    X'70'
01DFR         CLKAD   EQU   CLK+1
01E0R 0071    CØM     DC    X'0071'         GAIN,A/D CH 0,ENABLED,READ ØNE SAMP
01E1R         CMD     EQU   CØM+1
01E2R 2811    SHØW1   DC    X'2811',0,SH01
      0000
      01EER
01E8R 2811    SHØW2   DC    X'2811',0,SH02
      0000
      01F2R
01EER 0000    SH01    DC    0,1
      0001
01F2R 0000    SH02    DC    0,2
      0002
01F6R 3C0F    WRIT1   DC    X'3C0F',0,LØW1,HIGH1,0
      0000
      0222R
      6621R
      0000
0200R 3C0F    WRIT2   DC    X'3C0F',0,LØW2,HIGH2,0
      0000
      6622R
```

```
         CA21R
         0000
0064               NUMSEC  EQU   100
020AR              SAV     DS    2
020CR    0000      BREGS   DC    0,0,X'20',0,X'F1',LØW1+10,HIGH1,LØW2,HIGH2,X'70',X'48'
         0000
         0020
         0000
         00F1
         022CR
         6621R
         6622R
         CA21R
         0070
         0048
0222R              LØW1    DS    25600
6621R              HIGH1   EQU   *-1
6622R              LØW2    DS    25600
CA21R              HIGH2   EQU   *-1
CA22R                      END   STAR
```


NØ ERRØRS

```
ABØRT    0110R
ABØRT2   010ER
ABØRT3   0102R
AD       0002
BL       01DAR
BLANK    01D4R
BREGS    020CR
CLK      01DER
CLKAD    01DFR
CLR      002CR
CMD      01E1R
CØM      01E0R
CØUNT    0003
EØF      01C0R
GETSEC   01A4R
HIGH1    6621R
HIGH2    CA21R
LØW1     0222R
LØW2     6622R
LUP      0144R
MESS     01C6R
NUMSEC   0064
PACK     01ACR
PAWS     01B0R
QUIT     012AR
R0       0000
R1       0001
R11      000B
R12      000C
R13      000D
R14      000E
R15      000F
RDDSK    0170R
READGØ   0009
REWDSK   0182R
RHIGH1   0006
RHIGH2   0008
RLØW1    0005
RLØW2    0007
RSTØP    000A
SAV      020AR
SECMES   018ER
SECTRS   01C4R
SET1     0058R
SET2     00B2R
SHØ1     01EER
SHØ2     01F2R
SHØW1    01E2R
SHØW2    01E8R
SLCH     0004
STAR     0000R
TAPMES   01B2R
TØTAPE   0132R
UNPAK    0186R
UNPAK2   018AR
WAIT     00B0R
WRIT1    01F6R
WRIT2    0200R
WRTTP    017AR
SHØW2    01E8R
```

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Appendix D

TORNADO DATA ANALYSIS PROGRAMS

Listings and Example Printouts

Program SHOALL


```
$ASSM
SHØALL PRØG TØRNADØ PRØCESSØR PRØGRAM
 ERLST
$FØRT
C $LAB= SHØALL
C PRØGRAM TØ READ IN FRØM LU 1 THE
C RECØRDED DIGITIZED TØRNADØ SAMPLES
C IN 12800 15 BIT SAMPLE BLØCKS AND PLØT
C THEM ØN THE VARIAN.
C
      IMPLICIT INTEGER*2 (I-N)
      INTEGER*4 ISTAT,ISTDEV
      CØMPLEX CMPLX
      DIMENSIØN INP(12800),IPLØT(3),IGD(21),DAT(15)
      DIMENSIØN SPEC(513),TBL(514)
      CØMPLEX Z(1024)
      EQUIVALENCE (INP(1),DAT(1))
      DATA C215,IZERØ,IØNE/32768.,0,1/
      DATA ICR,IGDPTS,SCALE/3360,21,5./
      DATA LU/3/
      GDINC=1399./FLØAT(IGDPTS-1)
C SET UP GRID VALUES
      DØ 4 I=1,IGDPTS
      X=I-1
4     IGD(I)=X*GDINC+.5
      WRITE(0,1)
1     FØRMAT(6HLABEL?)
      READ (0,2) DAT
2     FØRMAT(15A4)
      WRITE(3,7) DAT,ICR
7     FØRMAT(1H ,15A4,A1)
      WRITE(0,21)
21    FØRMAT(13HNFFT,RECØRDS?)
      READ(0,17) N,NRECS
C SET RECØRD CØUNTER TØ 0
      NRECNT=0
C SET UP FFT TABLES
      CALL FØUR1T(Z,N,TBL,IZERØ)
      N2=N/2
      N21=N2+1
C ZERØ AVG SPECTRA
      DØ 20 I=1,N21
20    SPEC(I)=0.
      WRITE(0,14)
14    FØRMAT(38HDELAY(MS),THRESH(V),SPACE(MS),RATE(KS))
      READ(0,15) DELAY,THRESH,SPACE,RATE
15    FØRMAT(15F5.2)
C CØNVERT TØ INTERNAL PARAMETERS
C RATE IN SAMPS/SEC/SPACE BETWEEN VERTICAL LINES
C IN SECØNDS,DELAY FØR WINDØW IN SAMPLES,
C THRESHØLD IN INTEGER RANGE
      RATE=RATE*1000.
```

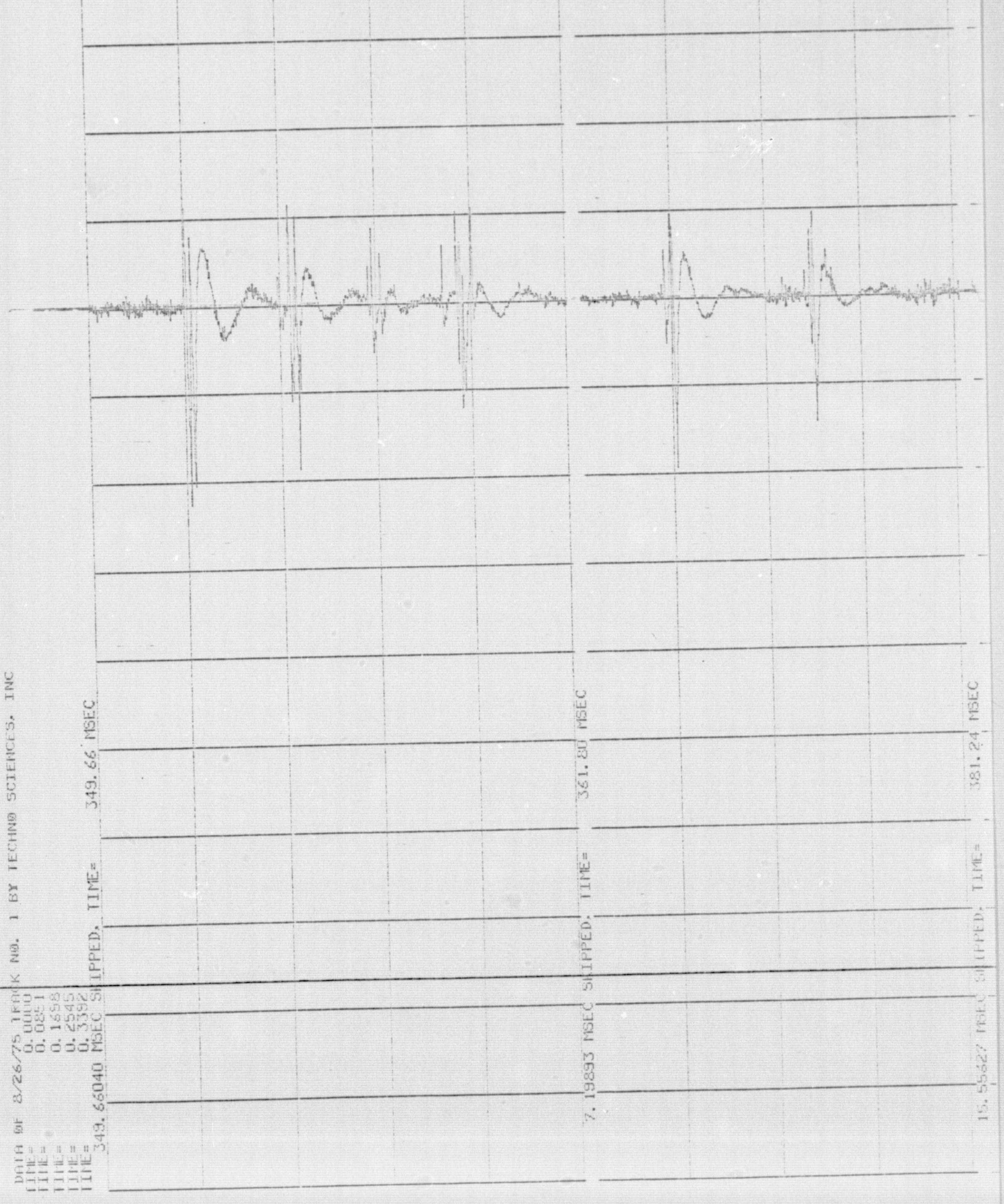
```
      SPACE=SPACE/1000.
      ISPAC=SPACE*RATE+.5
      DELAY=DELAY/1000.
      IDLY=DELAY*RATE+.5
      ITHRSH=(2.**14)*THRESH/10.
      DT=1./RATE
C GET EXPANSIØN FACTØR FØR PLØTTING
C IRPT=0 MEANS DØNT PLØT DATA
      WRITE(0,16)
16    FØRMAT(8HREPEATS?)
      READ(0,17)IRPTS
17    FØRMAT(15I5)
C ADJUST GRID SPACING FØR REPEATS
      ISPAC=ISPAC*IRPTS
      XRPT=IRPTS
      CALL SETGRD(LU,IGD,IGDPTS,ISPAC)
      ICNT=0
      SKIP=0.
      ISWICH=0
      TIME=0.
      XLAST=0.
      NFFT=0
5     CALL SYSIØ(72,1,ISTAT,ISTDEV,INP(1),INP(12800),2,0)
      IF(ISTAT.NE.0) GØ TØ 101
      IF(IRPT.NE.0) WRITE(3,100) TIME
      DØ 6 III=1,12800
      TIME=TIME+DT
100   FØRMAT(5HTIME=,F15.4)
      SKIP=SKIP+DT
      IF(ISWICH.EQ.1) GØ TØ 8
      IJ=III+IDLY
      IF(IJ.GT.12800) GØ TØ 6
      IF(IABS(INP(IJ)).LT.ITHRSH) GØ TØ 6
      ISWICH=1
      NFFT=0
      SKIPM=SKIP*1000.
      TIM=TIME*1000.
      WRITE(3,12) SKIPM,TIM
12    FØRMAT(1H ,F12.5,21H MSEC SKIPPED, TIME= ,F10.2,5H MSEC)
      GØ TØ 13
8     ICNT=ICNT+1
      IF(ICNT.LE.IDLY) GØ TØ 13
      ICNT=0
      LØ =III-IDLY
      IHI=III+IDLY
      IF(LØ.LT.1.ØR.IHI.GT.12800) GØ TØ 13
      IMAX=0
      DØ 11 II=LØ,IHI
      IMX=IABS(INP(II))
      IMAX=MAX0(IMAX,IMX)
      IF(IMAX.GE.ITHRSH) GØ TØ 13
11    CONTINUE
```

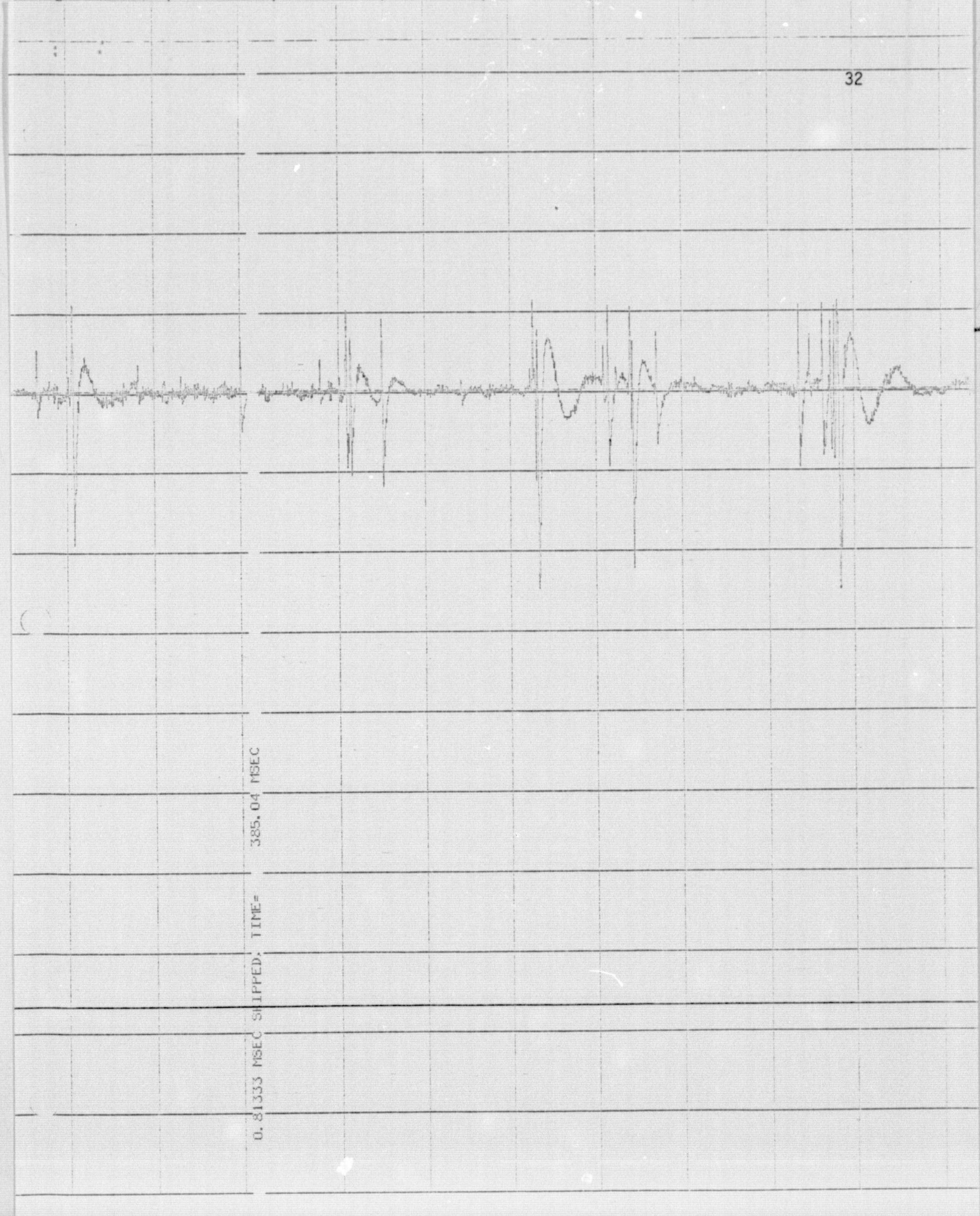
```
      ISWICH=0
      SKIP=0.
      GØ TØ 6
13    X=INP(III)
      X=X/C215
      NFFT=NFFT+1
      IF(N.EQ.0) GØ TØ 22
      Z(NFFT)=CMPLX(X,0.)
      IF(NFFT.LT.N) GØ TØ 22
      NFFT=0
      CALL FØUR1T(Z,N,TBL,IØNE)
      DØ 23 I=1,N21
      RE=REAL(Z(I))
      AI=AIMAG(Z(I))
23    SPEC(I)=SPEC(I)+RE*RE+AI*AI
C LINEARLY INTERPØLATE
22    IF(IRPTS.EQ.0) GØ TØ 6
      DØ 18 I=1,IRPTS
      XX=XLAST+FLØAT(I)*(X-XLAST)/XRPT
      K=(XX*SCALE+.5)*1399.+1.5
      K=MAX0(0,K)
      KK=MIN0(1399,K)
      IPLØT(1)=KK
      CALL PLØTIT(IPLØT,LL,IØNE,IØNE)
18    CØNTINUE
      XLAST=X
C RESET GRID IF TIME
6     CØNTINUE
      NRECNT=NRECNT+1
      IF(NRECNT.LT.NRECS) GØ TØ 5
101   IF(N.EQ.0) STØP
      XMAX=0.
C FIND AVG SPEC MAX
      DØ 24 I=1,N21
24    XMAX=AMAX1(XMAX,SPEC(I))
C PRINT IT
      DØ 25 I=1,N21
      K=SPEC(I)*1399/XMAX+.5
      IPLØT(1)=K
      DØ 25 J=1,10
      CALL PLØTIT(IPLØT,L,IØNE,IØNE)
25    CØNTINUE
      END
.U         EXT FUNC
ISTAT      INT4 VAR
ISTDEV     INT4 VAR
CMPLX      EXT FUNC
INP        INT2 VAR
IPLØT      INT2 VAR
IGD        INT2 VAR
DAT        REAL VAR
SPEC       REAL VAR
```

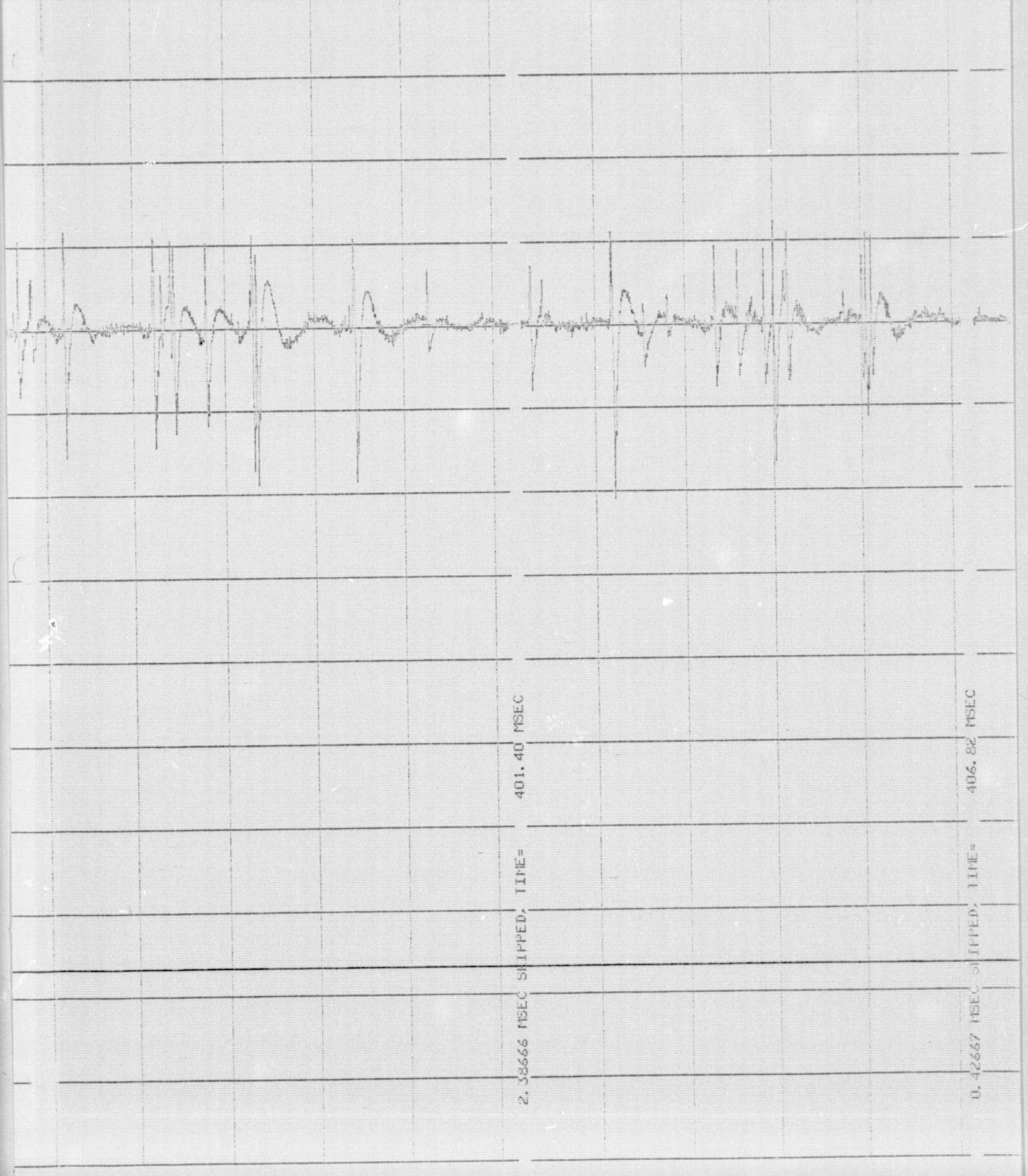
```
TBL       REAL VAR
E         CMPX VAR
C215      REAL VAR
IZERØ     INT2 VAR
IØNE      INT2 VAR
ICR       INT2 VAR
IGDPTS    INT2 VAR
SCALE     REAL VAR
LU        INT2 VAR
GDINC     REAL VAR
FLØAT     EXT FUNC
FLØAT2    EXT FUNC
4         LABEL
I         INT2 VAR
X         REAL VAR
.W        EXT FUNC
.Y        EXT FUNC
1         LABEL
@H        EXT FUNC
2         LABEL
7         LABEL
21        LABEL
17        LABEL
N         INT2 VAR
NRECS     INT2 VAR
NRECNT    INT2 VAR
FØURIT    EXT FUNC
N2        INT2 VAR
N21       INT2 VAR
20        LABEL
14        LABEL
15        LABEL
DELAY     REAL VAR
THRESH    REAL VAR
SPACE     REAL VAR
RATE      REAL VAR
ISPAC     INT2 VAR
IDLY      INT2 VAR
ITHRSH    INT2 VAR
.R        EXT FUNC
DT        REAL VAR
16        LABEL
IRPTS     INT2 VAR
XRPT      REAL VAR
SETGRD    EXT FUNC
ICNT      INT2 VAR
SKIP      REAL VAR
ISWICH    INT2 VAR
TIME      REAL VAR
XLAST     REAL VAR
NFFT      INT2 VAR
5         LABEL
```

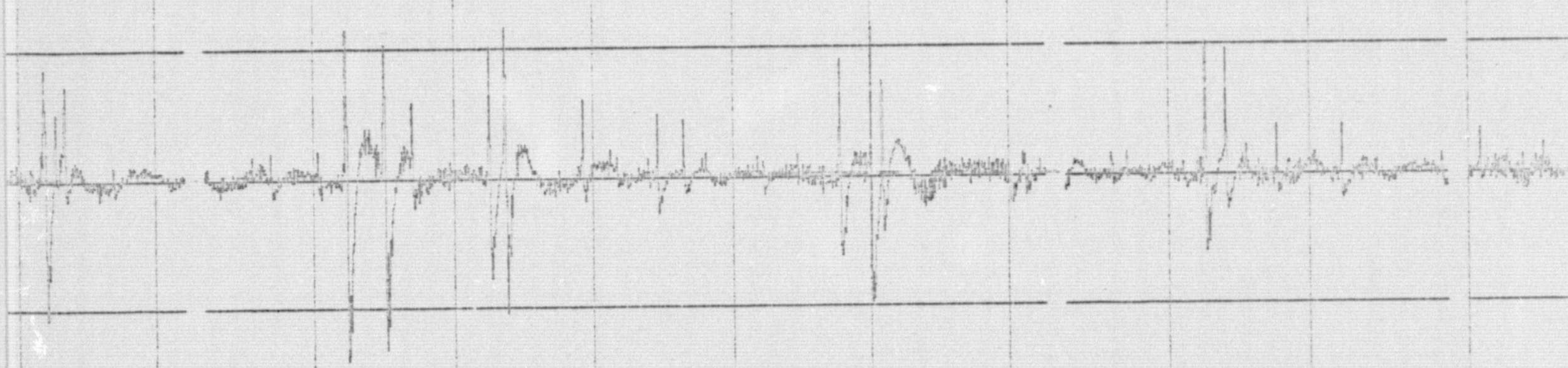
```
SYSIØ    EXT FUNC
101      LABEL
IRPT     INT2 VAR
100      LABEL
6        LABEL
III      INT2 VAR
8        LABEL
IJ       INT2 VAR
IABS     EXT FUNC
IABS2    EXT FUNC
SKIPM    REAL VAR
TIM      REAL VAR
12       LABEL
13       LABEL
LØ       INT2 VAR
IHI      INT2 VAR
IMAX     INT2 VAR
11       LABEL
II       INT2 VAR
IMX      INT2 VAR
MAX0     EXT FUNC
MAX02    EXT FUNC
22       LABEL
$P       EXT FUNC
23       LABEL
RE       REAL VAR
REAL     EXT FUNC
AI       REAL VAR
AIMAG    EXT FUNC
18       LABEL
XX       REAL VAR
K        INT2 VAR
KK       INT2 VAR
MIN0     EXT FUNC
MIN02    EXT FUNC
PLØTIT   EXT FUNC
LL       INT2 VAR
.S       EXT FUNC
XMAX     REAL VAR
24       LABEL
AMAX1    EXT FUNC
25       LABEL
J        INT2 VAR
L        INT2 VAR
.V       EXT FUNC

0000 ERRØRS
```

Example of SHOALL Printout




0.81333 MSEC SKIPPED. TIME= 385.04 MSEC


2.38666 MSEC SKIPPED, TIME= 401.40 MSEC
0.42667 MSEC SKIPPED, TIME= 406.82 MSEC

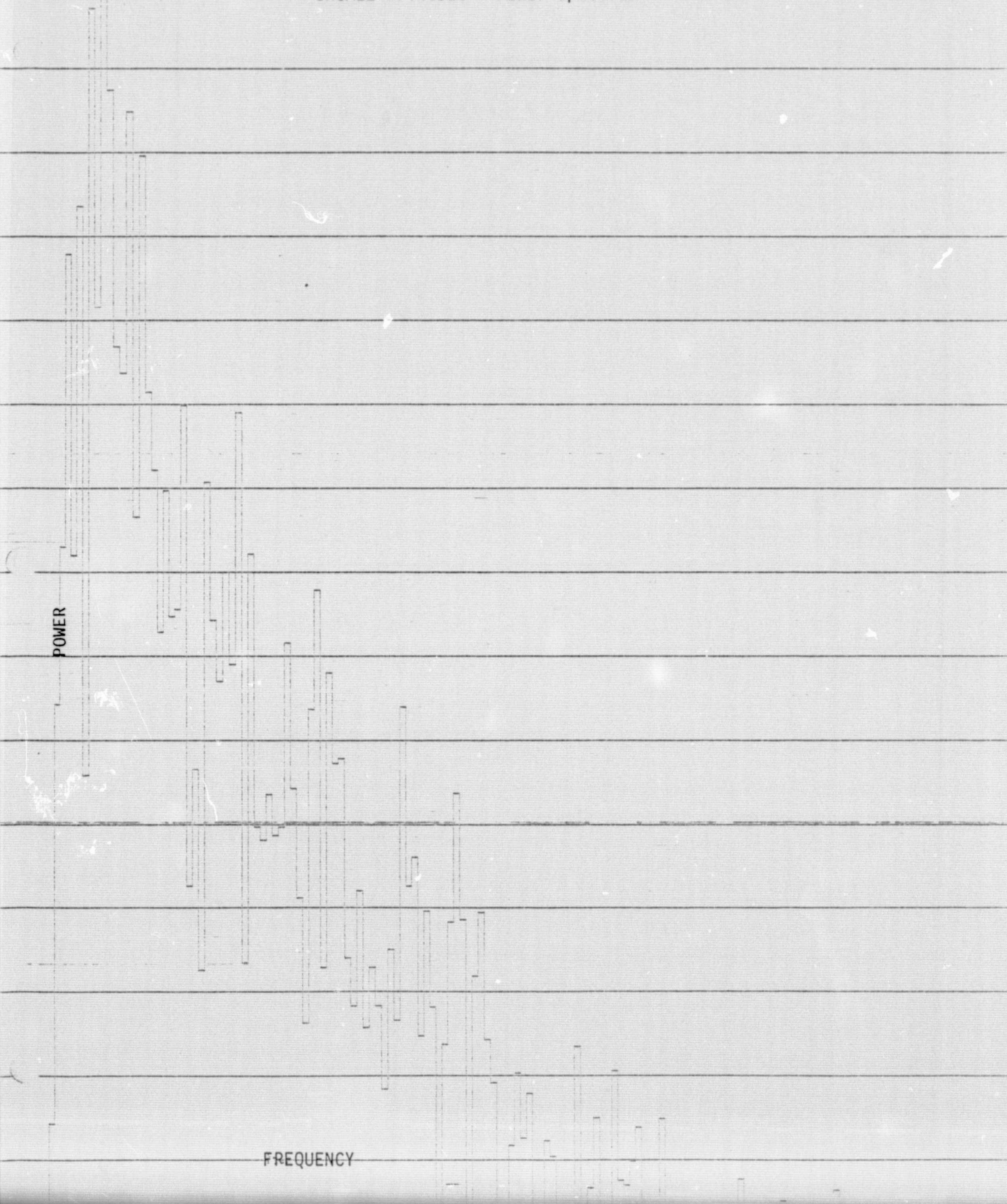


2.58666 MSEC SKIPPED, TIME= 411.38 MSEC

3.83332 MSEC SKIPPED, TIME= 421.18 MSEC

TIME= 0.4239

SHOALL Printout - Power Spectrum

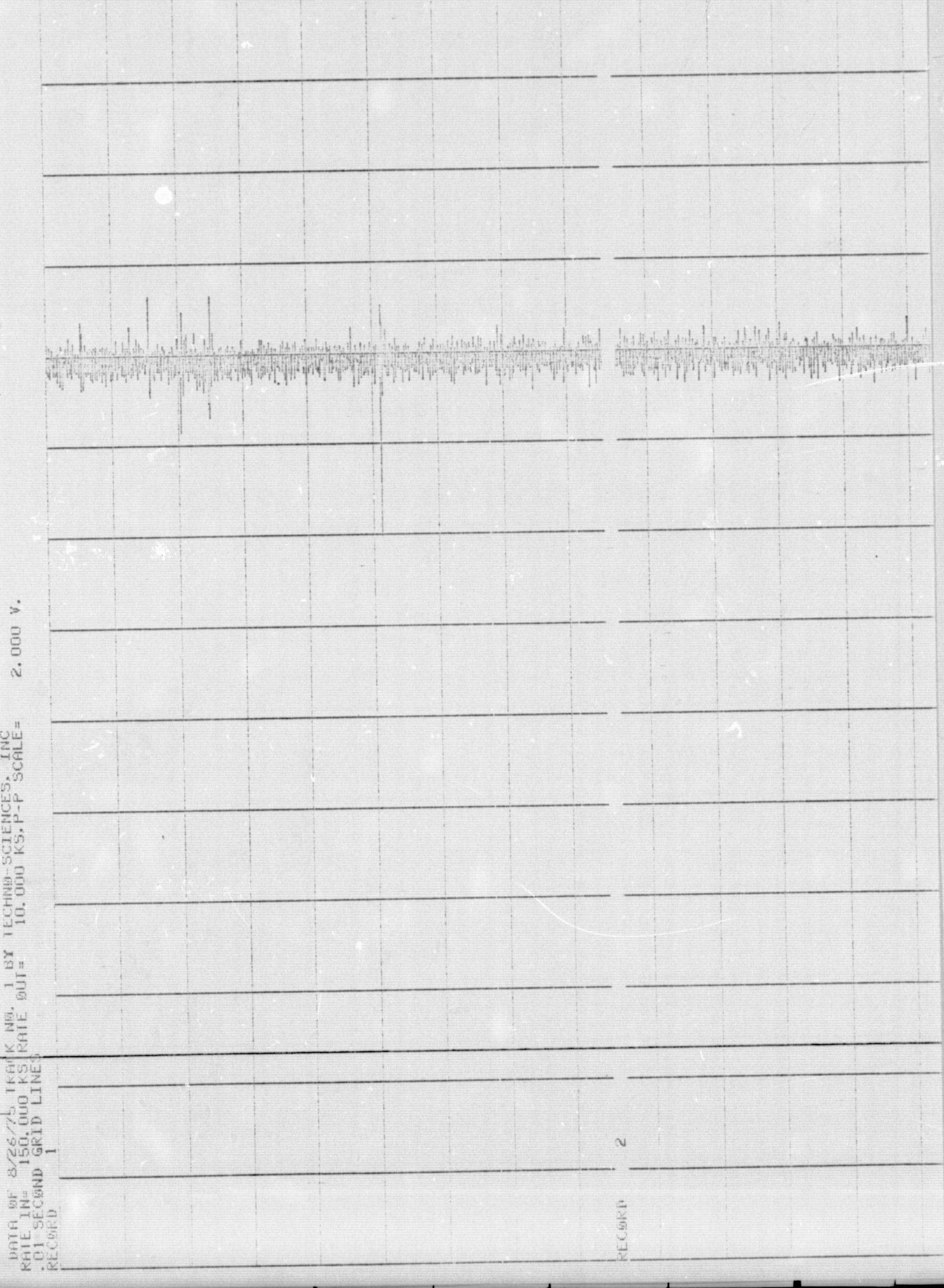


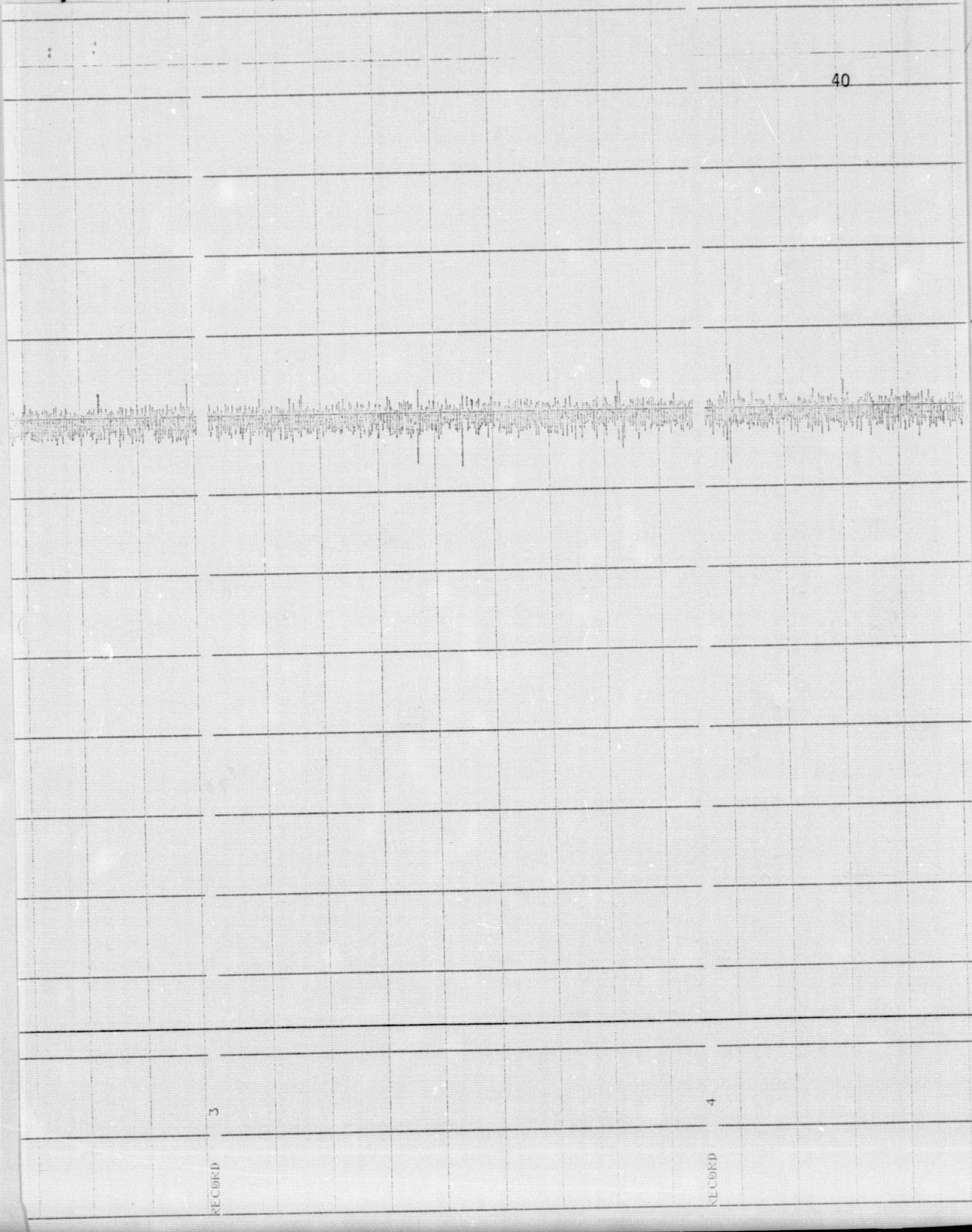
Program REDUCE - Program Listing

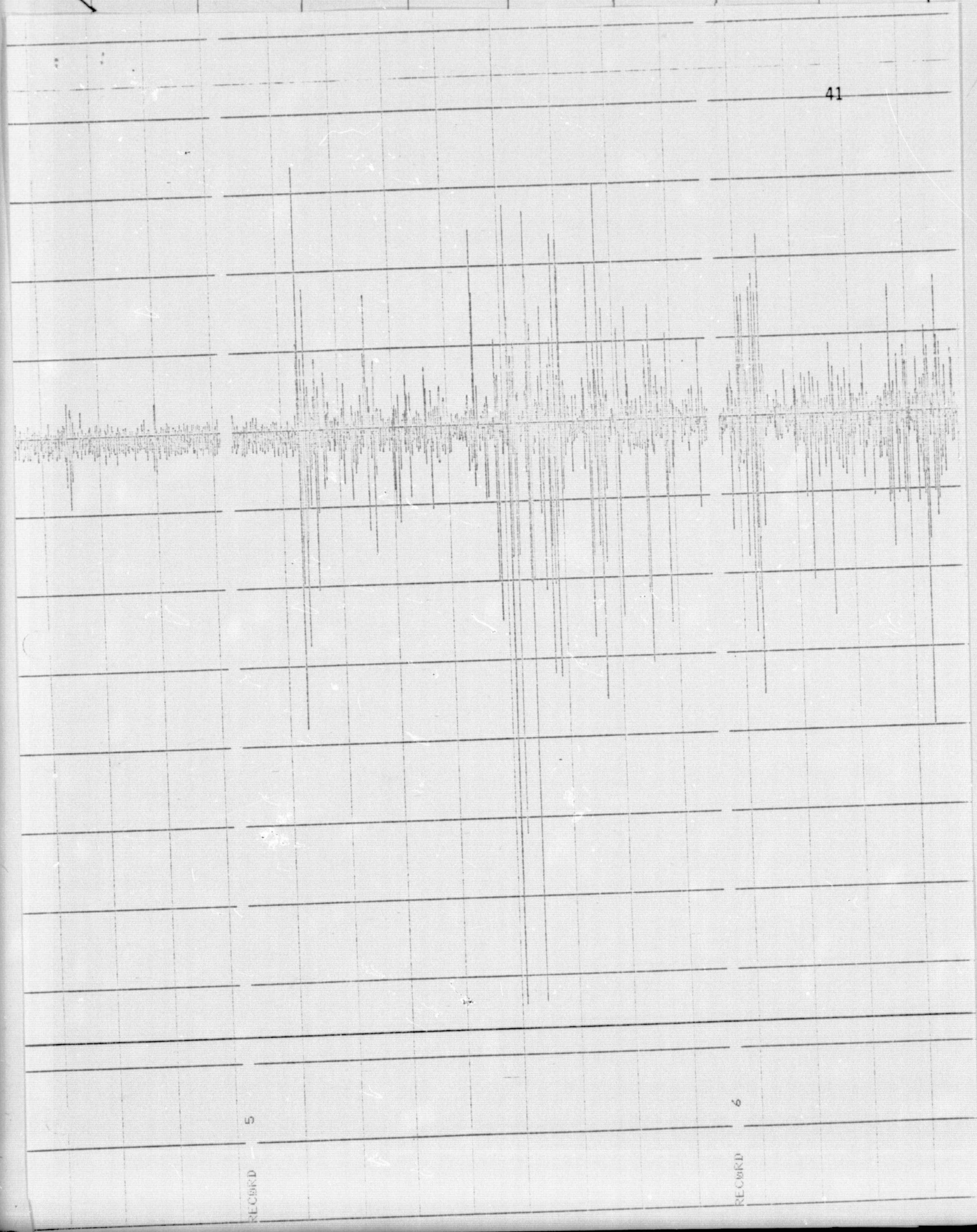

```
$ASSM
REDUCE PRØG TØRNADØ TIME CØMPRESSIØN PRØGRAM LDD 2/76
 ERLST
$FØRT
C $LAB= REDUCE
C PRØGRAM TØ READ IN TØRNADØ DATA
C RC FILTER WITH THE 3 DB PØINT AT
C 1/2 THE NYQUIST RATE FØR THE ØUTPUT
C PLØTTING SAMPLING RATE
C THE ØUTPUT RATE IS AN INPUT VARIABLE
C IN KSAMPS/SEC
C PLØTTING CØNTINUES TØ EØF
C LDD 12/9/75 MØD FØR 8/32 2/5/76
      IMPLICIT INTEGER*2 (I-N)
      INTEGER*4 ISTAT,ISTDEV
      DIMENSIØN INP(12800),IPLØT(10),IGD(21)
      DIMENSIØN DAT(15),LAST(10).
      DATA IGDPTS/21/
      DATA LU,IØNE/3,1/
      GDINC=1399./FLØAT(IGDPTS-1)
C SET UP GRID VALUES
      DØ 4 I=1,IGDPTS
      X=I-1
4     IGD(I)=X*GDINC+.5
      WRITE(0,1)
1     FØRMAT(6HLABEL?)
      READ(0,2) DAT
2     FØRMAT(15A4)
      WRITE(3,7) DAT
7     FØRMAT(1H ,15A4)
      WRITE(0,21)
21    FØRMAT(25HRATE IN,RATE ØUT,RANGE?   )
      READ(0,15) RATIN,RATØUT,RANGE
15    FØRMAT(15F5.2)
      WRITE(3,77) RATIN,RATØUT,RANGE
77    FØRMAT(8HRATE IN=,F9.3,4H KS,,9HRATE ØUT=,F9.3,4H KS,,
     1 10HP-P SCALE=,F9.3,3H V.)
      SCALE=20.*1399./RANGE
      ALPDEL=3.1415927*RATØUT/RATIN
      RHØ=EXP(-ALPDEL)
      ISEND=RATIN/RATØUT +.5
      ISPAC=10.*RATØUT+.5
C .01 SEC GRID LINES
      WRITE(3,80)
80    FØRMAT(21H.01 SECØND GRID LINES)
      CALL SETGRD(LU,IGD,IGDPTS,ISPAC)
      ICNT=0
      IREC=0
      Y=0.
      XNØRM=(2.**15)/SQRT(1.-RHØ*RHØ)
11    CALL SYSIØ(72,1,ISTAT,ISTDEV,INP(1),INP(12800),2,0)
      IF(ISTAT.EQ.0) GØ TØ 3
```

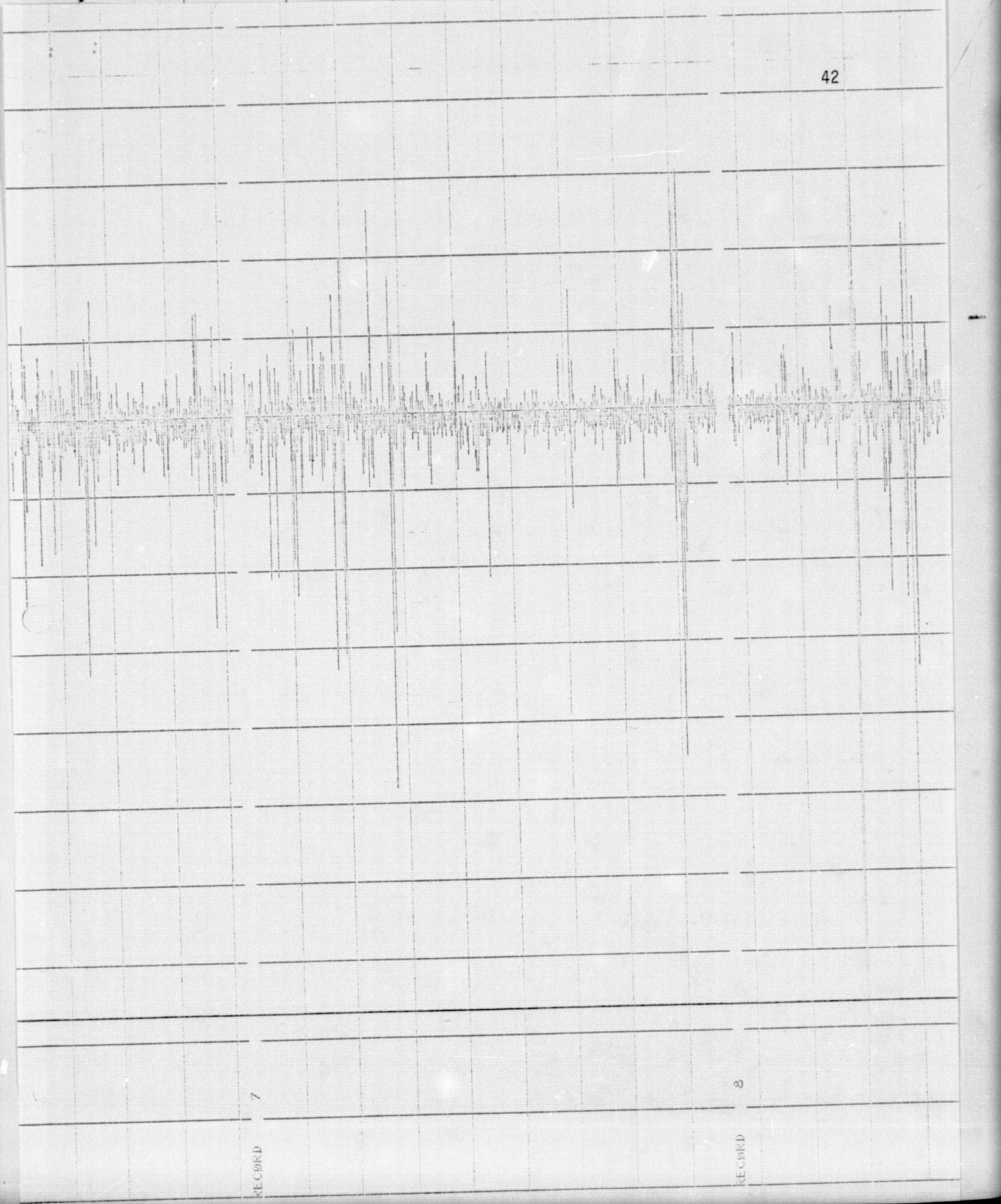
```
      WRITE(0,5) ISTAT
5     FØRMAT(8HSTATUS =,I6)
      STØP
3     IREC=IREC+1
      WRITE(3,8) IREC
8     FØRMAT(7HRECØRD ,I5)
      DØ 6 III=1,12800
      X=INP(III)
      Y=RHØ*Y+X/XNØRM
      ICNT=ICNT+1
      IF(ICNT.LT.ISEND) GØ TØ 6
      ICNT=0
      K=Y*SCALE+699.5
C 1 PØINT,1REPEAT,GRID ØN
      CALL PLØTIT(K,L,IØNE,IØNE)
      ISET=ISET+1
6     CØNTINUE
      GØ TØ 11
      END
.U         EXT FUNC
ISTAT      INT4 VAR
ISTDEV     INT4 VAR
INP        INT2 VAR
IPLØT      INT2 VAR
IGD        INT2 VAR
DAT        REAL VAR
LAST       INT2 VAR
IGDPTS     INT2 VAR
LU         INT2 VAR
IØNE       INT2 VAR
GDINC      REAL VAR
FLØAT      EXT FUNC
FLØAT2     EXT FUNC
4          LABEL
I          INT2 VAR
X          REAL VAR
.W         EXT FUNC
.Y         EXT FUNC
1          LABEL
@H         EXT FUNC
2          LABEL
7          LABEL
21         LABEL
15         LABEL
RATIN      REAL VAR
RATØUT     REAL VAR
RANGE      REAL VAR
77         LABEL
SCALE      REAL VAR
ALPDEL     REAL VAR
RHØ        REAL VAR
EXP        EXT FUNC
```

```
ISEND    INT2 VAR
ISPAC    INT2 VAR
80       LABEL
SETGRD   EXT FUNC
ICNT     INT2 VAR
IREC     INT2 VAR
Y        REAL VAR
XNØRM1   REAL VAR
.R       EXT FUNC
SQRT     EXT FUNC
11       LABEL
SYSIØ    EXT FUNC
3        LABEL
5        LABEL
.S       EXT FUNC
8        LABEL
6        LABEL
III      INT2 VAR
K        INT2 VAR
PLØTIT   EXT FUNC
L        INT2 VAR
ISET     INT2 VAR
.W       EXT FUNC

0000 ERRØRS
```


DATA OF 8/26/75 TRACK NO. 1 BY TECHNO-SCIENCES, INC
RATE IN= 150.000 KS RATE OUT= 10.000 KS.P-P SCALE= 2.000 V.
.01 SECOND GRID LINES
RECORD 1
RECORD 2


RECORD 3
RECORD 4


RECORD 5
RECORD 6


RECORD 7
RECORD 8

```
$ASSM
TØRNANAL PRØG TØRNADØ DATA ANALYSIS PRØG TSI 4/76
 ERLST
$FØRT
C PRØGRAM TØ READ  IN FRØM LU 1 THE
C RECØRDED DIGITIZED TØRNADØ SAMPLES
C IN 12800 15 BIT SAMPLE BLØCKS
C AND ANALYZE THEM FØR AMPLITUDE &
C TIME INTERVAL DISTRIBUTIØNS
C
      IMPLICIT INTEGER*2 (I-N)
      INTEGER*4 IPARM1(6)
      DIMENSIØN INP(12800),TIMPMF(1024),AMPMF(1024)
      DIMENSIØN IGRD(10),IDAT(5),IPARM(12),LAST(5)
      EQUIVALENCE (IPARM(1),IPARM1(1))
      DATA LU/3/
      DATA IRPTS/5/
      DATA IGDPTS/6/
      DATA IØNE,IM1,ITWØ/1,-1,2/
      DATA ITMMAX,IAMPMX/1024,1024/
C AMPLITUDE NØRMALIZER FØR PMF
      NØRM=32768/IAMPMX
C SET UP GRID PØINTS
      DØ 15 I=1,IGDPTS
15    IGRD(I)=FLØAT(I-1)*1399./FLØAT(IGDPTS-1) +.5
      CALL SETGRD(LU,IGRD,IGDPTS,0)
      WRITE(0,1)
1     FØRMAT(27HRECØRDS,DUR,THRESH?(2I5,F5))
      READ(0,20) NRECS,IDUR,THRESH
20    FØRMAT(2I5,F5)
C CØNVERT TØ INTEGER THRESHØLD
      ITHRSH=(2.**14)*THRESH/10.
C + ØR - 10. V RANGE
C CLEAR PMF ARRAYS
      DØ 2 I=1,ITMMAX
2     TIMPMF(I)=0.
      DØ 3 I=1,IAMPMX
3     AMPMF(I)=0.
C SET PEAK ØRIGIN TØ 0
C AND PEAK EVENT CNTR ALSØ
      IPKØRG=0
      IEVENT=0
C SET LAST ØNE IN TØ 0
      LASTIN=0
      DØ 4 IIII=1,NRECS
      CALL SYSIØ(IPARM1,72,1,INP(1),25600,0)
      IF(IPARM(2).NE.0) GØ TØ 5
C EXIT
      DØ 6 III=1,12800
      IPKØRG=IPKØRG+1
      IEVENT=IEVENT+1
      K=(INP(III)+16384)/NØRM +1
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      AMPMF(K)=AMPMF(K)+1.
      IF(INP(III).LT.ITHRSH) GØ TØ 6
      IF(LASTIN.GT.ITHRSH) GØ TØ 6
C IF NØT. THIS AN UP-CRØSSING
      IF(IPKØRG.LT.IDUR) GØ  TØ 16
C SKIP SHØRT INTERVALS(PART ØF SAME EVENT)
      IEVENT=IEVENT/IDUR
      IEVENT=MINO(IEVENT.ITMMAX)
C NØRMALIZED TØ EVENT LENGTHS
      TIMPMF(IEVENT)=TIMPMF(IEVENT)+1.
      IEVENT=0
16    IPKØRG=0
6     LASTIN=INP(III)
4     CØNTINUE
      GØ TØ 12
C ABNØRMAL END
5     WRITE(0.13) IIII.IPARM(2)
13    FØRMAT(10HØN RECØRD .I5. 9H.STATUS= .I6)
12    CØNTINUE
C NØRMALIZE&PLØT PMF'S
      SUM=0.
      DØ 8 I=1.ITMMAX
8     SUM=SUM+TIMPMF(I)
      WRITE(3.18) NRECS.THRESH.SUM
18    FØRMAT(1H .I6.10H RECØRDS ..11H THRESHØLD=.F8.3.
     1 F12.0.21H TIME INTERVALS FØUND)
      WRITE(3.19)
19    FØRMAT(20HLØG10 ØF PRØBABILITY   )
      WRITE(3.21)
21    FØRMAT(2H-5.33X.2H-4.33X.2H-3.33X.2H-2.33X.2H-1)
      CDF=1.
      LAST(2)=0
      LAST(1)=0
      DØ 9 I=1.ITMMAX
      TIMPMF(I)=TIMPMF(I)/SUM
      IDAT(1)=280.*(ALØG10(AMAX1(.00001.TIMPMF(I)))+5.)+.5
      CDF=CDF-TIMPMF(I)
      IDAT(2)=280.*(ALØG10(AMAX1(.00001.CDF))+5.)+.5
      DØ 9 J=1.IRPTS
      CALL PLØTIT(IDAT.LAST.ITWØ.IØNE)
9     CØNTINUE
      SUM=0.
      DØ 10 I=1.IAMPMX
10    SUM=SUM+AMPMF(I)
      CDF=1.
      LAST(1)=0
      LAST(2)=0
      DØ 11 I=1.IAMPMX
      AMPMF(I)=AMPMF(I)/SUM
      IDAT(1)=280.*(ALØG10(AMAX1(.00001.AMPMF(I)))+5.)+.5
      CDF=CDF-AMPMF(I)
      IDAT(2)=280.*(ALØG10(AMAX1(.00001.CDF))+5.)+.5
```

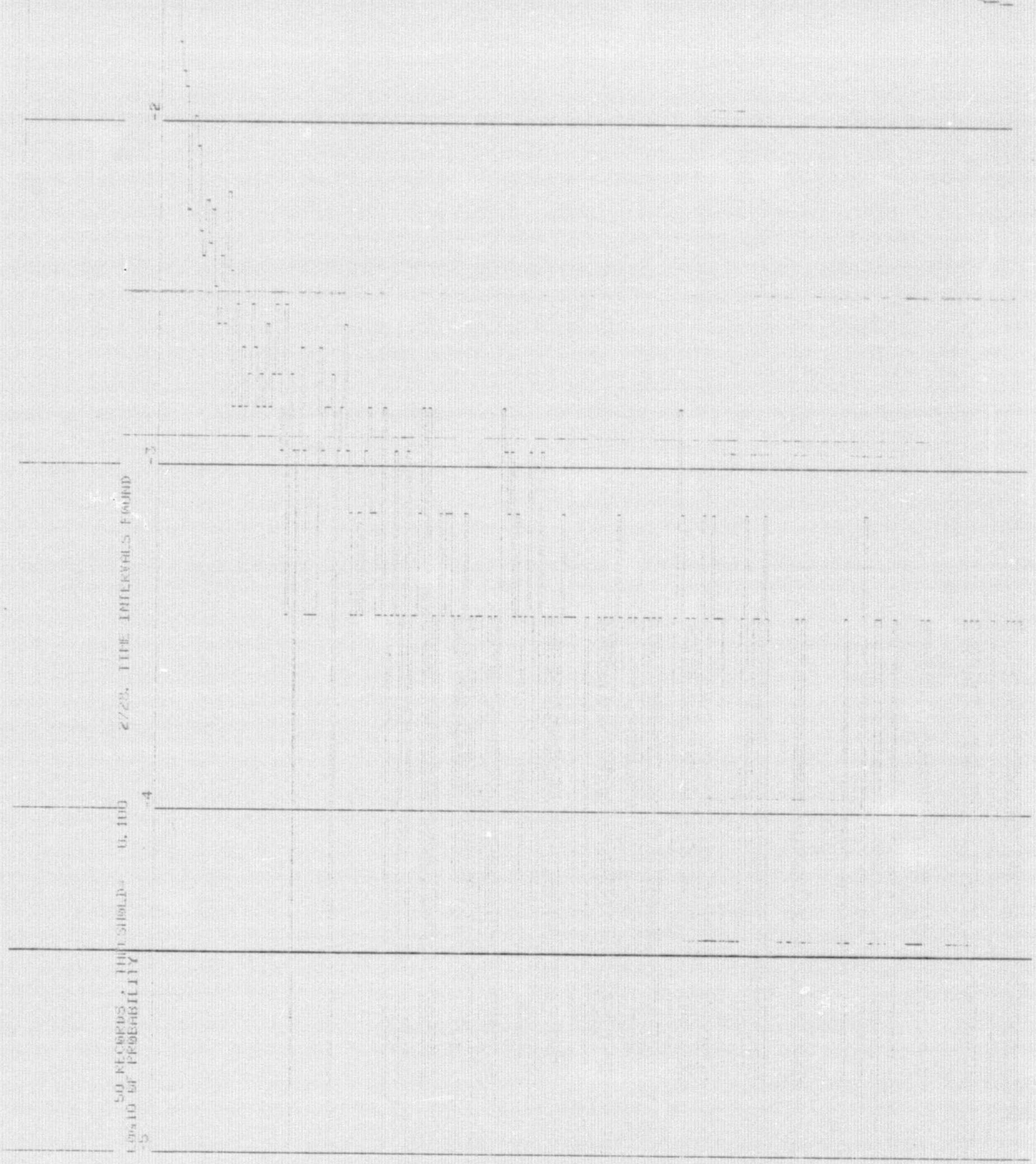
ORIGINAL PAGE IS
OF POOR QUALITY

```
      DØ 11 J=1.IRPTS
      CALL PLØTIT(IDAT,LAST,ITWØ,IØNE)
11    CØNTINUE
      STØP
      END
.U         EXT FUNC
IPARM1     INT4 VAR
INP        INT2 VAR
TIMPMF     REAL VAR
AMPMF      REAL VAR
IGRD       INT2 VAR
IDAT       INT2 VAR
IPARM      INT2 VAR
LAST       INT2 VAR
LU         INT2 VAR
IRPTS      INT2 VAR
IGDPTS     INT2 VAR
IØNE       INT2 VAR
IM1        INT2 VAR
ITWØ       INT2 VAR
ITMMAX     INT2 VAR
IAMPMX     INT2 VAR
NØRM       INT2 VAR
15         LABEL
I          INT2 VAR
FLØAT      EXT FUNC
FLØAT2     EXT FUNC
.Y         EXT FUNC
SETGRD     EXT FUNC
1          LABEL
@H         EXT FUNC
20         LABEL
NRECS      INT2 VAR
IDUR       INT2 VAR
THRESH     REAL VAR
ITHRSH     INT2 VAR
.R         EXT FUNC
2          LABEL
3          LABEL
IPKØRG     INT2 VAR
IEVENT     INT2 VAR
LASTIN     INT2 VAR
4          LABEL
IIII       INT2 VAR
SYSIØ      EXT FUNC
5          LABEL
6          LABEL
III        INT2 VAR
K          INT2 VAR
16         LABEL
MINO       EXT FUNC
MINO2      EXT FUNC
```

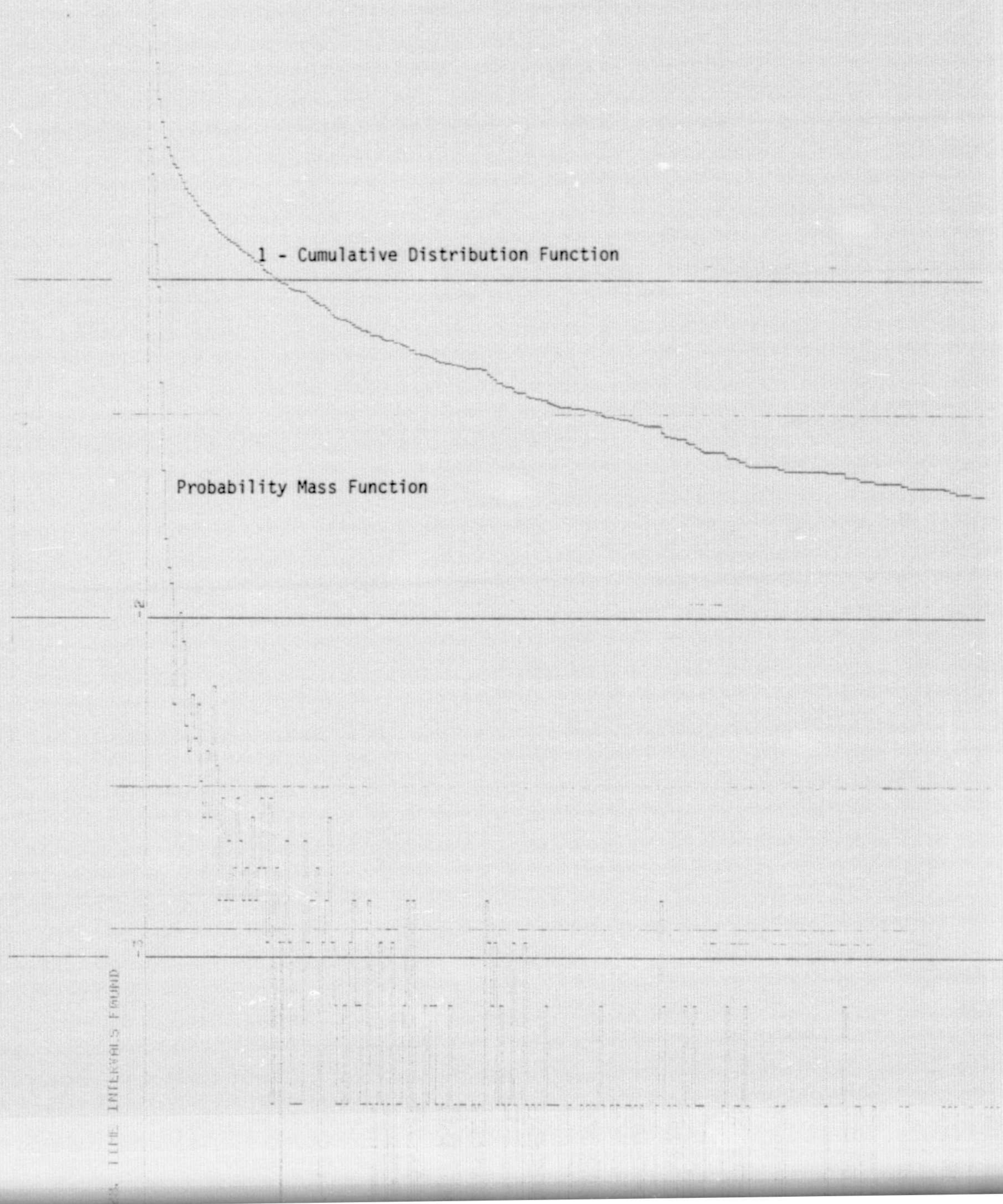
ORIGINAL PAGE IS
OF POOR QUALITY

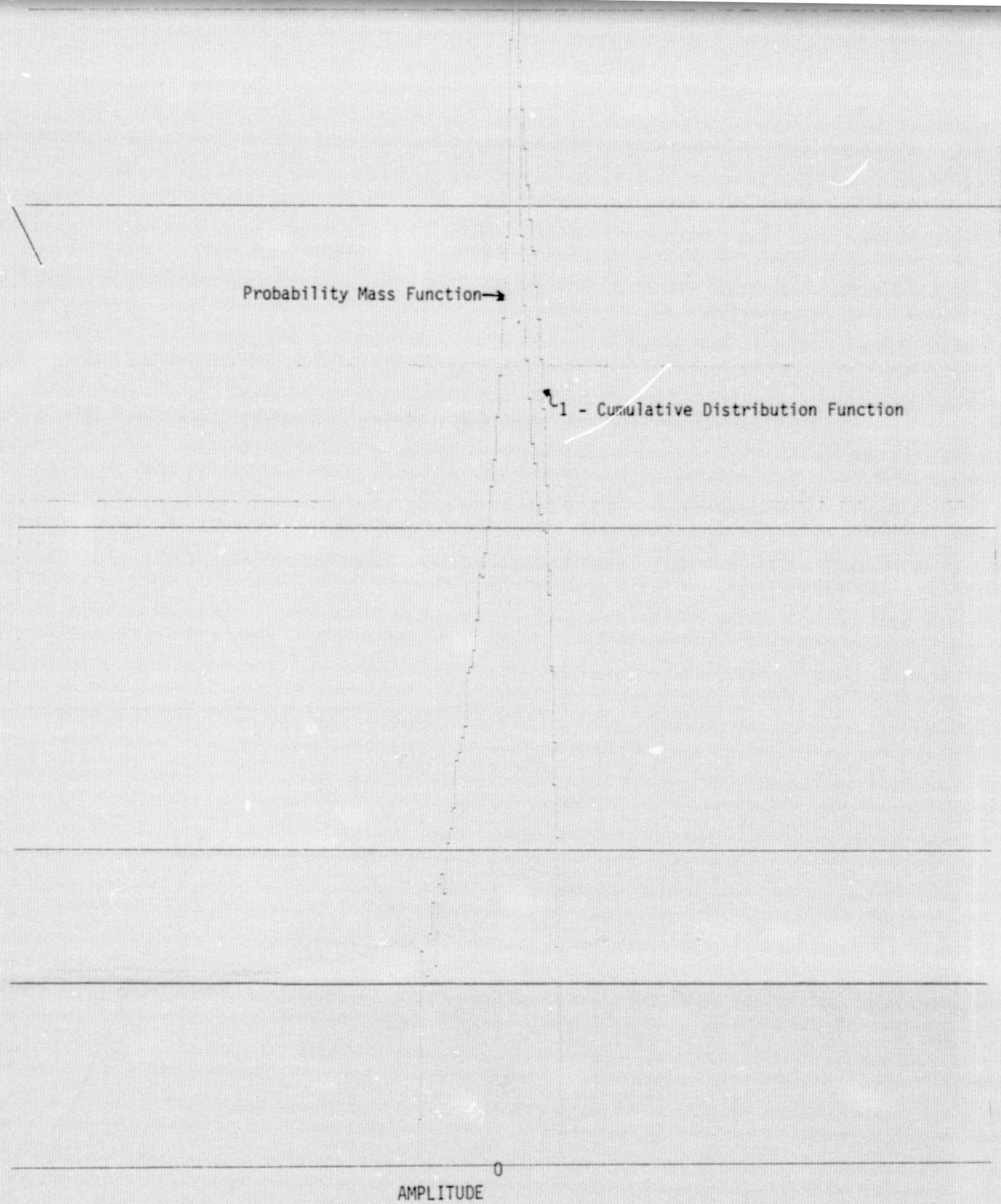
```
12       LABEL
13       LABEL
SUM      REAL VAR
8        LABEL
18       LABEL
19       LABEL
21       LABEL
CDF      REAL VAR
9        LABEL
ALØG10   EXT FUNC
AMAX1    EXT FUNC
J        INT2 VAR
PLØTIT   EXT FUNC
10       LABEL
11       LABEL
.S       EXT FUNC
.V       EXT FUNC

0000 ERRØRS:  FØRTRAN V LEVEL 1 R03-00
```

Probability Mass Function

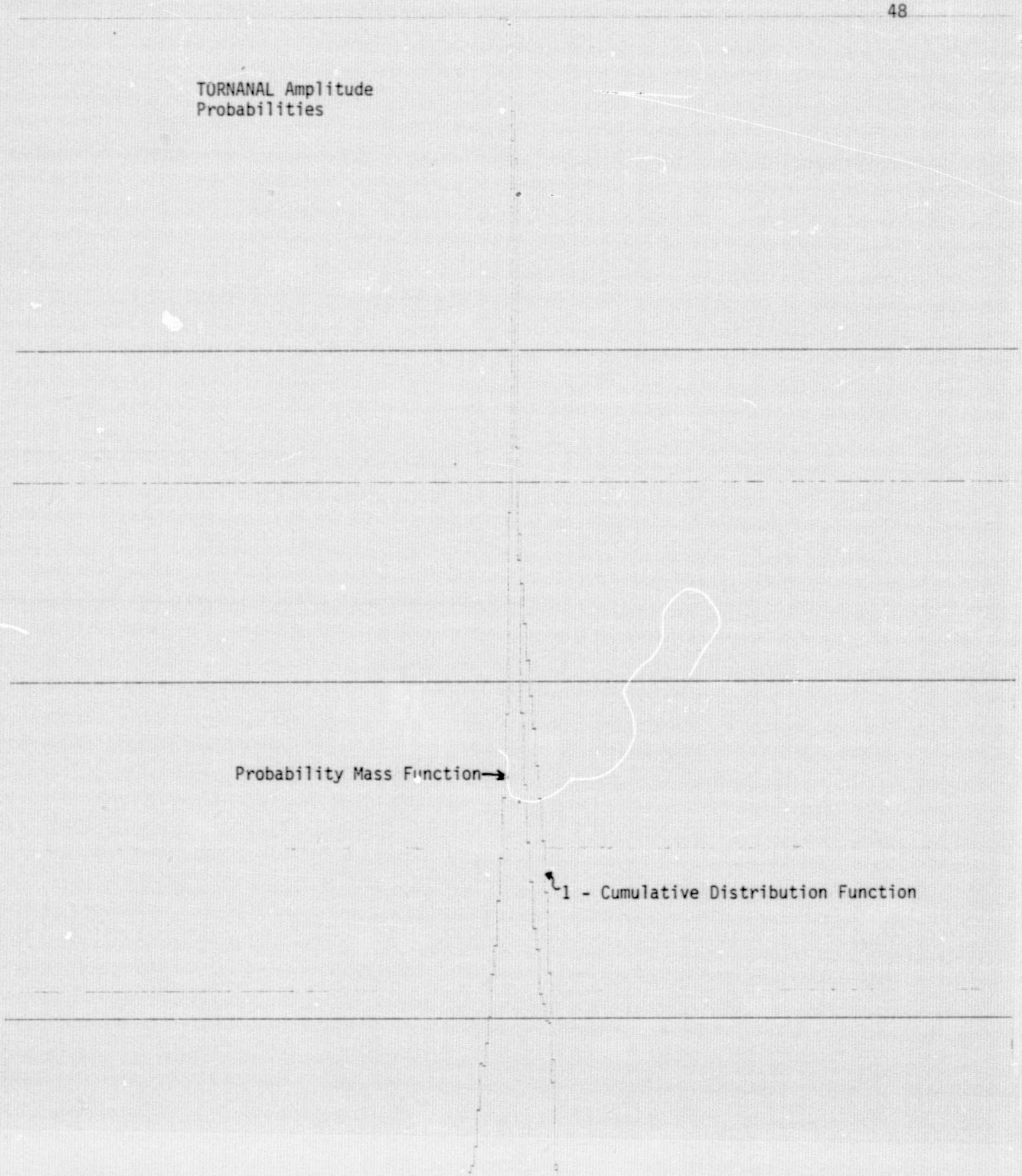


Time Between Peaks →


1 - Cumulative Distribution Function
Probability Mass Function
-2
-3



FOLDOUT FRAME


TORNANAL Amplitude
Probabilities
Probability Mass Function
1 - Cumulative Distribution Function

Appendix E

Program ECKPDF

Program Listing and Sample Printout

Program ECKPDF - Program Listing

```
$ASSM
ECKPDF PROG PDF DATA ANALYSIS PROGRAM 5/76
 ERLST
$FORT
      IMPLICIT INTEGER*2 (I-N)
      INTEGER*4 IPARM(6)
      INTEGER*4 IHEDCK,IHED(40)
      DIMENSION INN(1030),INP(2048),DAT(40),ISTAT(2)
      DIMENSION IPLOT(1400),LAST(10)
      DIMENSION PULSE(2048),VAR(2048)
      DIMENSION PDF(256),IGRD(10)
      DIMENSION INEW(1400)
      DIMENSION TBL(512)
      COMPLEX Z(512),CMPLX
      DIMENSION PAV(512)
      EQUIVALENCE (Z(1),PULSE(1)),(PAV(1),VAR(1))
      EQUIVALENCE(INN(1),IHEDCK),(IPARM(1),ISTAT(1))
      DATA IONE,IZERO,I8,ITWO,I3,I256/1,0,8,2,3,256/
      DATA ISPAC,IRPT,MAXPLS/128,8,256/
      DATA IBIG,IAMP/30000,2/
      DATA DELTAT/.01/
C DELTAT=SAMPLING PERIOD(MSEC)
      DATA NFFT/256/
      DATA LU,YES/3,1HY/
      DATA DTOR,DLT300/.01745329,3./
C DTOR=DEGREES TO RADIANS,DLT300=300XSAMPLING PERICD(MICSEC)
      DATA I6,IM1/6,-1/
      DATA IGRD(1),IGRD(2),IGRD(3),IGRD(4),IGRD(5),IGRD(6)/
     1 0,279,559,839,1119,1399/
C GET IHEDER IN
      CALL SYSIO(IPARM,72,1,IHED(1),80,0)
      CALL FOUR1T(Z,NFFT,TBL,IZERO)
C SET UP FFT TABLES
      NFFT21=NFFT/2+1
      WRITE(0,40)
40    FORMAT(12HY FOR PULSES)
      READ(0,50) PRPULS
50    FORMAT(A1)
      WRITE(0,4)
4     FORMAT(6H LABEL)
      READ(0,5) DAT
5     FORMAT(40A4)
      WRITE(0,30)
30    FORMAT(28H ANGLE,BMWIDTH,ALTUD(M),F5.1)
      READ(0,31) ANGLE,BEAM,ALTUD
C CONVERT TO RADIANS FOR LATER TRIG
      ANGRAD=ANGLE*DTOR
      BMRAD=BEAM*DTOR
C ONE SIDED BEAMWIDTH
      BM2=BMRAD/2.
C ADJUST MIN ANGLE FOR NADIR OR NOT
      ANGMIN=AMAX1(0.,ANGRAD-BM2)
```

```
C ALSO MAX
      ANGMAX=ANGRAD+BM2
C DXR= X INCREMENT ALONG THE GROUND WHEN ADJUSTING PULSE BASE
C CHOSEN SO THAT NO. OF GROUND SAMPS=NO. OF TIME SAMPS
C FROM NADIR TO ANGMAX
      DXR=SIN(ANGMAX)*DLT300/(2.*ALTUD*(1.-COS(ANGMAX)))
C NOW DO SAME FOR UNIFORM ANGLES
      DANG=DLT300*ANGMAX/(2.*ALTUD*(1./COS(ANGMAX)-1.))
31    FORMAT(8F5.1)
C CLEAR PDF ARRAY
      DO 42 I=1,256
42    PDF(I)=0.
C CLEAR AVG PULSE ARRAY
      DO 60 I=1,2048
      VAR(I)=0.
60    PULSE(I)=0.
      WRITE(0,1)
1     FORMAT(7H FILE=?)
      READ (0,2) IFILE
2     FORMAT(8I5)
      WRITE(0,7)
7     FORMAT(34HBLOCKS,BLKSIZE,DOCSIZE,LRECL,LO,HI   )
      READ(0,2) IBLKS,IRECS,IDOCS,IDATS,LO,IHI
      IDOCS1=1+IDOCS/2
      IREC2=IRECS/2
      IDATS2=IDATS/2
      LO=MAX0(1,LO)
      IHI=MIN0(IHI,IDATS)
      IHI=MAX0(NFFT+LO-1,IHI)
      IHIGH=IHI-LO+1
      IHIGH=MIN0(IHIGH,466)
      IHIGH2=2*IHIGH
C ALLOW FOR 3 TRACES
      IHIGHU=IHIGH*3
      SAMPS=IHIGH
      DUR=DELTAT*SAMPS
      IBEG=IDOCS1
      KTOT=0
      DO 9 IIII=1,IBLKS
      IF(IBEG.EQ.IDOCS1)CALL SYSIO(IPARM,72,1,INN(1),2060,0)
      IF(ISTAT(2).EQ.0) GO TO 128
      WRITE(0,80) ISTAT(2)
80    FORMAT(7HSTATUS= ,I6)
      GO TO 28
128   IF(IHEDCK.NE.IHED(1)) GO TO228
      WRITE(0,81)
81    FORMAT(12HHEADER FOUND)
      GO TO 28
C TERMINATE ON LAST IHEDER FOUND TOO
228   CALL BYTOHW(INN(IBEG),IDATS,INP(1),I8)
      IBEG=IBEG+IDATS2
      IF(IBEG.GT.IREC2) IBEG=IDOCS1
```

```
100   FORMAT(25I4)
      KTOT=KTOT+1
      DO 17 K=LO,IHI
      I=INP(K)+1
      X=I-1
      PULSE(K)=PULSE(K)+X
      VAR(K)=X*X+VAR(K)
17    PDF(I)=PDF(I)+1.
200   FORMAT(4E20.9)
9     CONTINUE
   28 SUM=0.
      DO 8 I=1,256
8     SUM=SUM+PDF(I)
      XMAX=0.
      DO 10 I=1,256
      PDF(I)=PDF(I)/SUM
10    XMAX=AMAX1(XMAX,PDF(I))
      WRITE(3,6) DAT
6     FORMAT(1H ,40A4)
C PUT OUT TAPE HEADER STUFF
      WRITE(3,6) IHED
      WRITE(3,3) IFILE,ANGLE,DUR,SAMPS,ALTUD
3     FORMAT(6H FILE ,I3,5X,F6.1,8H DEGREES,5X,F6.2,7H MICSEC,
     15X,F7.2,8H PTS. IN,10H,ALTITUDE=, F5.0)
      WRITE(3,20) KTOT,LO,IHI
20    FORMAT(1H ,I6,7H BLOCKS,8H,LIMITS=,2I6)
      WRITE(3,21)
21    FORMAT(20HLOG OF PROBABILITY   )
      WRITE(3,22)
22    FORMAT(2H-5,33X,2H-4,33X,2H-3,33X,2H-2,33X,2H-1,33X,1H0)
      CALL SETGRD(LU,IGRD,I6,ISPAC)
      DO 12 I=1,256
      IDAT=280.*(ALOG10(AMAX1(.00001,PDF(I)))+5.)+.5
      DO 12 J=1,IRPT
12    CALL PLOTIT(IDAT,IDAT,IONE,IM1)
      WRITE(3,63)
63    FORMAT(20H1AVERAGE PULSE,SIGMA )
C GET AVG PULSE,PEAK
      PK=0.
      XTOT=KTOT
      DO 61 I=LO,IHI
      PULSE(I)=PULSE(I)/XTOT
      VAR(I)=VAR(I)/XTOT-PULSE(I)**2
      IF(PK.GT.PULSE(I)) GO TO 61
      PK=PULSE(I)
      KSTART=I-4
61    CONTINUE
      DELTAR=ALTUD*(1./COS(ANGRAD+BM2)-1./COS(ANGMIN))
      DELTAS=2.*DELTAR/DLT300
      KEND=DELTAS+.5
      KEND=KEND+KSTART
      WRITE(3,151) KSTART,KEND
```

```
151    FORMAT(7HSTART =,I6,7H, END =,I6)
C FIRST FIND ZERO
       PD0=0.
       DO 51 I=1,256
       PD0=PD0+PDF(I)
       IF(PD0.LT..0001) GO TO 51
       KZERO=I-1
       GO TO 52
51     CONTINUE
52     CONTINUE
C NOW FIND ADJUSTED AVERAGE PULSE
       XZERO=KZERO
       PK=PK-XZERO
       DO 64 K=LO,IHI
       PULSE(K)=PULSE(K)-XZERO
64     CONTINUE
C SET GRID FOR AVG PULSE
       CALL SETGRD(LU,IGRD,I6,IBIG)
       SCALE=1399./PK
       DO 62 K=LO,IHI
       IPLOT(1)=SCALE*PULSE(K)+.5
       IPLOT(2)=SCALE*SQRT(AMAX1(0.,VAR(K)))+.5
       IF(K.NE.LO) GO TO 72
       LAST(1)=IPLOT(1)
       LAST(2)=IPLOT(2)
72     CONTINUE
C FORCE GRID AT KSTART
       IF(K.EQ.KSTART.OR.K.EQ.KEND) CALL SETGRD(LU,IGRD,I6,IBIG)
       DO 62 J=1,IRPT
       CALL PLOTIT(IPLOT,LAST,ITWO,IONE)
62     CONTINUE
C ADJUST TIME BASE
C FOR UNIFORM SAMPLING ON GROUND
C GET START SAMPLE VALUE ON INPUT(MAY BE -)
       DRSTRT=ALTUD*(1./COS(ANGMIN)-1.)
       K0=KSTART-IFIX(2.*DRSTRT/DLT300+.5)
C NORMALIZED RANGE VALUES USED
C DTOT=TOTAL SURFACE COVERED
       DTOT=DXR*FLOAT(IHIGH)*ALTUD
       WRITE(3,25)ALTUD,DTOT
       LAST(1)=0
       KSET=0
       DO 48 K=1,IHIGH
       XR=DXR*FLOAT(K-1)
       RNS=1.+XR*XR
       DR=ALTUD*(SQRT(RNS)-1.)
       DS=2.*DR/DLT300
       KD=DS
C XR=NORMALIZED X,RNS=NORMALIZED RANGE,DR=RANGE CHANGE
C KD=TRUNCATED SAMPLE CHANGE
       KADJ=K0+KD
       IF(KADJ.NE.KSTART.AND.KADJ.NE.KEND)GO TO 58
```

```
      IF(KSET.EQ.1.AND.KADJ.EQ.KSTART) GO TO 49
      KSET=1
       CALL SETGRD(LU,IGRD,I6,IBIG)
58    IF(KADJ.GT.LO.AND.KADJ.LT.IHI) GO TO 49
      IPLOT(1)=0
      GO TO 57
49    IPLOT(1)=SCALE*(PULSE(KADJ)+(PULSE(KADJ+1)-
     1 PULSE(KADJ))*(DS-FLOAT(KD)))+.5
57    DO 48 I=1,IRPT
      CALL PLOTIT(IPLOT,LAST,IONE,IONE)
48    CONTINUE
C NOW PUT OUT UNIFORM ANGLE PULSES DANG=DELTA ANGLE
      KSET=0
      LAST(1)=0
      ANGTOT=DANG*FLOAT(IHIGH)
      ANGTOT=180.*ANGTOT/3.1415927
      WRITE(3,66) ANGTOT
66    FORMAT(6H10 TO ,F9.2,8H DEGREES)
      DO 67 K=1,IHIGH
      ANG=DANG*FLOAT(K-1)
      DR=ALTUD*(1./COS(ANG)-1.)
      DS=2.*DR/DLT300
      KD=DS
C ANG=ANGLE FROM NADIR,DR=RANGE CHANGE FROM NADIR,
C KD= TRUNCATED SAMPLE CHANGE
      KADJ=K0+KD
      IF(KADJ.NE.KSTART.AND.KADJ.NE.KEND) GO TO 68
      IF(KSET.EQ.1.AND.KADJ.EQ.KSTART) GO TO 69
      KSET=1
      CALL SETGRD(LU,IGRD,I6,IBIG)
C PUT VERTICAL LINE HERE
68    IF(KADJ.GT.LO.AND.KADJ.LT.IHI)GO TO 69
      IPLOT(1)=0
      GO TO 79
69    IPLOT(1)=SCALE*(PULSE(KADJ)+(PULSE(KADJ+1)-
     1 PULSE(KADJ))*(DS-FLOAT(KD)))+.5
79    DO 67 I=1,IRPT
      CALL PLOTIT(IPLOT,LAST,IONE,IONE)
67    CONTINUE
C SET UP GRID
      CALL SETGRD(LU,IGRD,IZERO,MAXPLS)
      WRITE(0,65)
65    FORMAT(25HPOSITION TAPE FOR PULSES)
      PAUSE
C PUT LINE AT PULSE START,END
      IPLOT(1)=0
      IPLOT(2)=IHIGH-1
      IPLOT(3)=IHIGH2-1
C GET MAX RANGE ADJUST FACTOR
C R**4 FACTOR
      WRITE(3,25) ALTUD,DTOT
25    FORMAT(12H1ALTITUDE = ,F7.0,2H M,22H DURATION FROM NADIR =,
```

```
    1 F7.0,2H M)
C CLEAR AVG SPEC ARRAY
      DO 89 I=1,512
89    PAV(I)=0.
C CLEAR PROB ARRAY
      DO 77 I=1,256
77    PDF(I)=0.
      MAXAMP=256*IAMP
      MAXAM1=MAXAMP-2
      TIMINC=ITMINC
      IBEG=IDOCS1
      DO 70 IIII=1,IBLKS
      IF(IBEG.EQ.IDOCS1)CALL SYSIO(IPARM,72,1,INN(1),2060,0)
      IF(ISTAT(2).NE.0)GO TO 78
      CALL BYTOHW(INN(IBEG),IDATS,INP(1),I8)
      IBEG=IBEG+IDATS2
      IF(IBEG.GT.IREC2)IBEG=IDOCS1
      MAX=0
      MIN=MAXAMP
      DO 71 K=LO,IHI
      I=MAX0(0,INP(K)-KZERO)*IAMP
      J=K-LO+1
      INEW(J)=I
      MIN=MIN0(MIN,I)
      MAX=MAX0(MAX,I)
71    INP(K)=I
C MAX=MAX VALUE OF ADJUSTED DATA,MIN=MINIMUM
      DO 24 K=1,IHIGH
      XR=DXR*FLOAT(K-1)
C NEW X VALUE
      ALF=ATAN(XR)
      X=1.39*(ALF-ANGRAD)/BM2
      SX=ABS(SIN(X))
      IF(SX.GT.X/2.) GO TO 26
      ANTFAC=1.
      GO TO 27
26    ANTFAC=(X/SX)**4
C  GET RANGE NORMALIZED SQUARED
27    RNS=1.+XR*XR
C GET RANGE AND ANTENNA ADJUSTMENT FACTOR
      RADJ=RNS*RNS
C DR= ACTUAL RANGE TO GROUND POINT - ALTITUDE
      DR=ALTUD*(SQRT(RNS)-1.)
      DS=2.*DR/DLT300
C TRUNCATED SAMPLE TIME(MAY BE -)
      KD=DS
      KADJ=K0+KD
C INDEX OVER FOR TIME PULSE
      J=K+IHIGH
      IF(KADJ.GE.LO.AND.KADJ.LT.IHI)GO TO 91
C IF -, FILL IN WITH 0
      INEW(J)=0
```

```
      GO TO 24
91    DX=INP(KADJ+1)-INP(KADJ)
C INTERPOLATE
      INEW(J)=RADJ*(FLOAT(INP(KADJ))+DX*(DS-FLOAT(KD)))+.5
      MIN=MIN0(MIN,INEW(J))
      MAX=MAX0(MAX,INEW(J))
24    CONTINUE
C SET FIRST PEAK INDICATOR
      NOPEAK=0
      DO 97 I=1,NFFT
      J=I+IHIGH
      IF(4*INEW(J).LT.MAX) GO TO 95
C ABOVE THRESH, POSSIBLE PEAK
      IF(INEW(J).GT.INEW(J+1)) GO TO 95
C DOWNHILL,DOESNT COUNT
      IF(INEW(J+1).LE.INEW(J+2)) GO TO 95
C STILL UP HILL
      IPKN=J+1
      IF (NOPEAK.EQ.0) GO TO 94
C FIRST PEAK
       K=IPKN-NOPEAK
      K=MAX0(IONE,K)
      K=MIN0(I256,K)
      PDF(K)=PDF(K)+1.
94    NOPEAK=IPKN
95    X=INEW(J)
      X=SQRT(AMAX1(0.,X))
97    Z(I)=CMPLX(X,0.)
      CALL FOUR1T(Z,NFFT,TBL,IONE)
      DO 98 I=1,NFFT21
98    PAV(I)=CABS(Z(I))**2+PAV(I)
      IF(PRPULS.NE.YES) GO TO 70
      DO 84 K=1,IHIGH
      ANG=DANG*FLOAT(K-1)
      DR=ALTUD*(1./COS(ANG)-1.)
      DS=2.*DR/DLT300
      KD=DS
      KADJ=K0+KD
      J=K+IHIGH2
C PUT THIS LINEAR ANGLE PLOT 3D IN LINE
      IF(KADJ.GE.LO.AND.KADJ.LT.IHI)GO TO 85
      INEW(J)=0
      GO TO 84
85    DX=INP(KADJ+1)-INP(KADJ)
      INEW(J)=FLOAT(INP(KADJ))+DX*(DS-FLOAT(KD))+.5
      MIN=MIN0(MIN,INEW(J))
      MAX=MAX0(MAX,INEW(J))
84    CONTINUE
      MAX=MIN0(MAX,MAXAMP)
C FILL IN TOP BLANKS
      IF(MAX.EQ.MAXAMP) GO TO 46
      DO 45 I=MAX,MAXAM1
```

```
45     CALL PLOTIT(IPLOT,IPLOT,I3,IZERO)
46     DO 41 I=MIN,MAX
       ICNT=3
       IR=MAX+MIN-I
C FORCE END=0
       DO 43 K=1,IHIGHU
       IF((INEW(K)-IR)*(INEW(K+1)-IR).GT.0) GO TO 43
C PULSE POINT FOUND
       ICNT=ICNT+1
       IPLOT(ICNT)=K-1
43     CONTINUE
       CALL PLOTIT(IPLOT,IPLOT,ICNT,IZERO)
41     CONTINUE
       IF(MIN.EQ.0) GO TO 70
C FILL IN LOWER BLANKS
       DO 47 I=1,MIN
47     CALL PLOTIT(IPLOT,IPLOT,I3,IZERO)
70     CONTINUE
78     LAST(1)=0
       PM=0.
       FMAX=1./(2.*DXR*ALTUD)
       WRITE(3,93) FMAX
93     FORMAT(21HLOG10 SPECTRUM,FMAX =,F9.5,6H CYC/M )
       WRITE(3,22)
       DO 96 I=2,NFFT21
96     PM=AMAX1(PM,PAV(I))
       CALL SETGRD(LU,IGRD,I6,ISPAC)
       DO 99 I=1,NFFT21
       IPLOT(1)=1399.*(ALOG10(AMAX1(1.E-5,PAV(I)/PM))/5.+1.)+.5
       DO 99 J=1,IRPT
99     CALL PLOTIT(IPLOT,LAST,IONE,IONE)
       DELTX=DXR*ALTUD
       WRITE(3,73) DELTX
73     FORMAT(30H1LOG OF PROB(SPACING),DELTA X= ,F9.5)
       WRITE(3,22)
       CALL SETGRD(LU,IGRD,I6,ISPAC)
       SUM=0.
       DO 82 I=1,256
82     SUM=SUM+PDF(I)
       DO 83 I=1,256
       PDF(I)=PDF(I)/SUM
       IDAT=280.*(ALOG10(AMAX1(.00001,PDF(I)))+5.)+.5
       DO 83 J=1,IRPT
83     CALL PLOTIT(IDAT,IDAT,IONE,IM1)
       STOP
       END
.U        EXT FUNC
IPARM     INT4 VAR
IHEDCK    INT4 VAR
IHED      INT4 VAR
INN       INT2 VAR
INP       INT2 VAR
```

```
JAT      REAL VAR
ISTAT    INT2 VAR
IPLOT    INT2 VAR
LAST     INT2 VAR
PULSE    REAL VAR
VAR      REAL VAR
PDF      REAL VAR
IGRD     INT2 VAR
INEW     INT2 VAR
TBL      REAL VAR
Z        CMPX VAR
CMPLX    EXT FUNC
PAV      REAL VAR
IONE     INT2 VAR
IZERO    INT2 VAR
I8       INT2 VAR
ITWO     INT2 VAR
I3       INT2 VAR
I256     INT2 VAR
ISPAC    INT2 VAR
IRPT     INT2 VAR
MAXPLS   INT2 VAR
IBIG     INT2 VAR
IAMP     INT2 VAR
DELTAT   REAL VAR
NFFT     INT2 VAR
LU       INT2 VAR
YES      REAL VAR
DTOR     REAL VAR
DLT300   REAL VAR
I6       INT2 VAR
IM1      INT2 VAR
SYSIO    EXT FUNC
FOUR1T   EXT FUNC
NFFT21   INT2 VAR
40       LABEL
@H       EXT FUNC
50       LABEL
PRPULS   REAL VAR
4        LABEL
5        LABEL
30       LABEL
31       LABEL
ANGLE    REAL VAR
BEAM     REAL VAR
ALTUD    REAL VAR
ANGRAD   REAL VAR
BMRAD    REAL VAR
BM2      REAL VAR
ANGMIN   REAL VAR
AMAX1    EXT FUNC
ANGMAX   REAL VAR
```

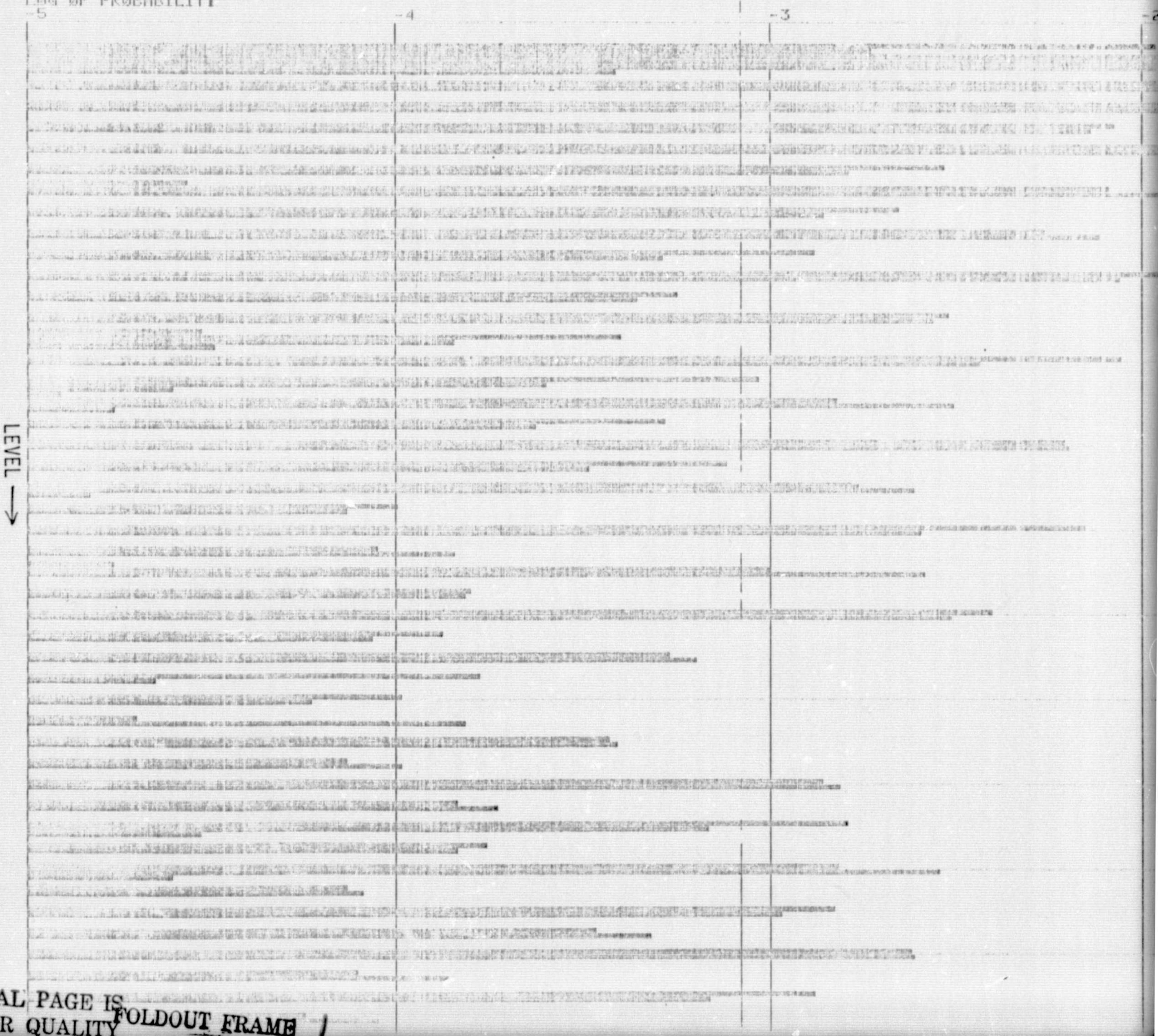
```
DXR      REAL VAR
SIN      EXT FUNC
COS      EXT FUNC
DANG     REAL VAR
42       LABEL
I        INT2 VAR
60       LABEL
1        LABEL
2        LABEL
IFILE    INT2 VAR
7        LABEL
IBLKS    INT2 VAR
IRECS    INT2 VAR
IDOCS    INT2 VAR
IDATS    INT2 VAR
LO       INT2 VAR
IHI      INT2 VAR
IDOCS1   INT2 VAR
IREC2    INT2 VAR
IDATS2   INT2 VAR
MAX0     EXT FUNC
MAX02    EXT FUNC
MIN0     EXT FUNC
MIN02    EXT FUNC
IHIGH    INT2 VAR
IHIGH2   INT2 VAR
IHIGHU   INT2 VAR
SAMPS    REAL VAR
.W       EXT FUNC
DUR      REAL VAR
IBEG     INT2 VAR
KTOT     INT2 VAR
9        LABEL
IIII     INT2 VAR
128      LABEL
80       LABEL
28       LABEL
228      LABEL
81       LABEL
BYTOHW   EXT FUNC
100      LABEL
17       LABEL
K        INT2 VAR
X        REAL VAR
200      LABEL
SUM      REAL VAR
8        LABEL
XMAX     REAL VAR
10       LABEL
6        LABEL
3        LABEL
20       LABEL
```

```
21        LABEL
22        LABEL
SETGRD    EXT FUNC
12        LABEL
IDAT      INT2 VAR
ALOG10    EXT FUNC
.Y        EXT FUNC
J         INT2 VAR
PLOTIT    EXT FUNC
63        LABEL
PK        REAL VAR
XTOT      REAL VAR
61        LABEL
.R        EXT FUNC
KSTART    INT2 VAR
DELTAR    REAL VAR
DELTAS    REAL VAR
KEND      INT2 VAR
151       LABEL
PD0       REAL VAR
51        LABEL
KZERO     INT2 VAR
52        LABEL
XZERO     REAL VAR
64        LABEL
SCALE     REAL VAR
62        LABEL
SQRT      EXT FUNC
72        LABEL
DRSTRT    REAL VAR
K0        INT2 VAR
IFIX      EXT FUNC
DTOT      REAL VAR
FLOAT     EXT FUNC
FLOAT2    EXT FUNC
25        LABEL
KSET      INT2 VAR
48        LABEL
XR        REAL VAR
RNS       REAL VAR
DR        REAL VAR
DS        REAL VAR
KD        INT2 VAR
KADJ      INT2 VAR
58        LABEL
49        LABEL
57        LABEL
ANGTOT    REAL VAR
66        LABEL
67        LABEL
ANG       REAL VAR
68        LABEL
```

69	LABEL
79	LABEL
65	LABEL
.H	EXT FUNC
89	LABEL
77	LABEL
MAXAMP	INT2 VAR
MAXAM1	INT2 VAR
TIMINC	REAL VAR
ITMINC	INT2 VAR
70	LABEL
78	LABEL
MAX	INT2 VAR
MIN	INT2 VAR
71	LABEL
24	LABEL
ALF	REAL VAR
ATAN	EXT FUNC
SX	REAL VAR
ABS	EXT FUNC
26	LABEL
ANTFAC	REAL VAR
27	LABEL
RADJ	REAL VAR
91	LABEL
DX	REAL VAR
NOPEAK	INT2 VAR
97	LABEL
95	LABEL
IPKN	INT2 VAR
94	LABEL
$P	EXT FUNC
98	LABEL
CABS	EXT FUNC
84	LABEL
85	LABEL
46	LABEL
45	LABEL
41	LABEL
ICNT	INT2 VAR
IR	INT2 VAR
43	LABEL
47	LABEL
PM	REAL VAR
FMAX	REAL VAR
93	LABEL
96	LABEL
99	LABEL
DELTX	REAL VAR
73	LABEL
82	LABEL
83	LABEL

```
 S        EXT FUNC
.V        EXT FUNC

0000 ERRORS:   FORTRAN V LEVEL 1 R03-00
```

ALTITUDE = 1800. M DURATION FROM NADIR = 2164. M
*.BG>
DA252/75 9/9/75.LINE=5.RUN=1.EPLANE STICK.ALT=6KFT.
FILE 1 18.0 DEGREES 4.00 MICSEC 400.00 PTS. IN.ALTITUDE= 1800.
1024 BLOCKS.LIMITS= 1 400
LOG OF PROBABILITY



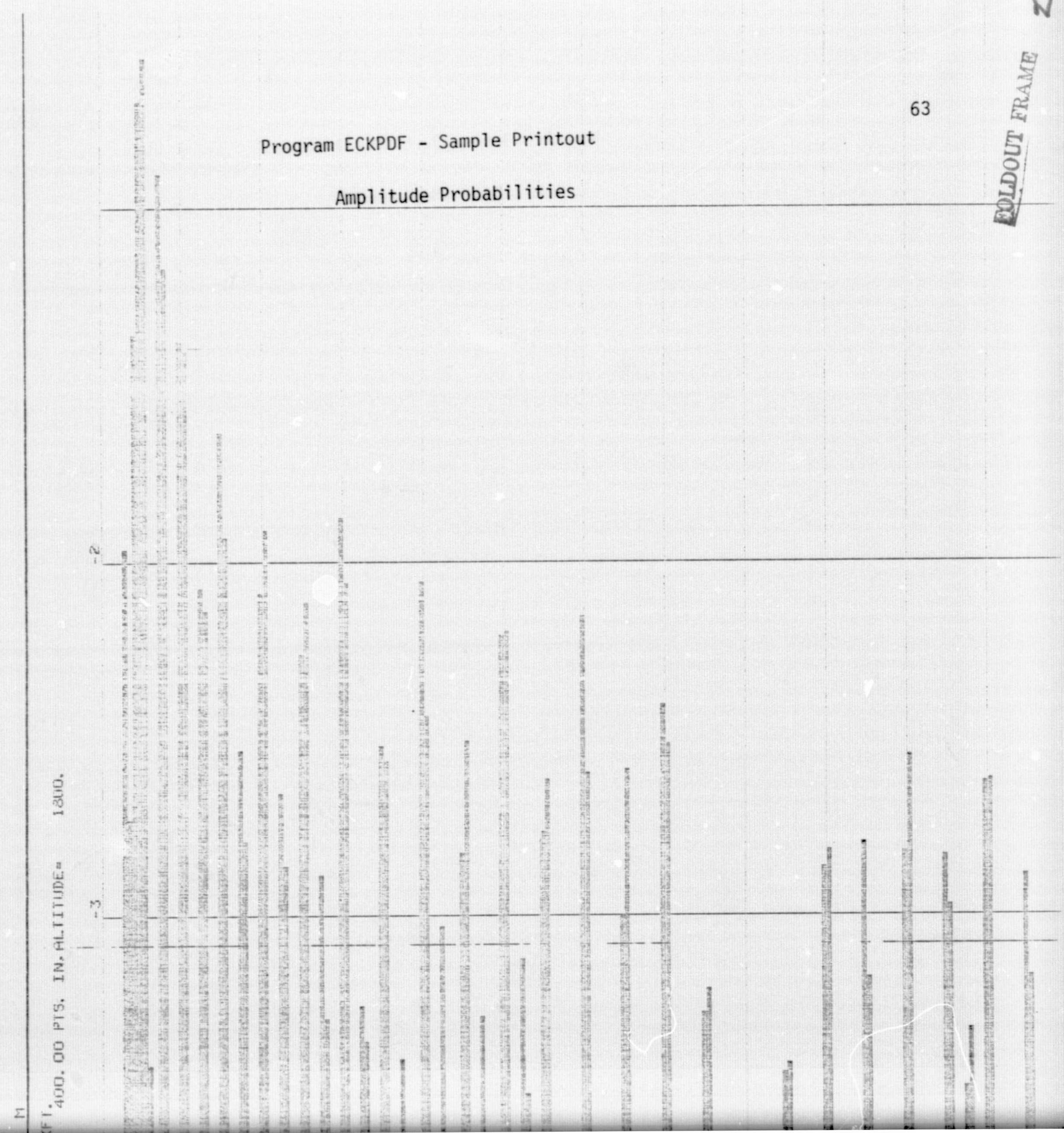
ORIGINAL PAGE IS
OF POOR QUALITY

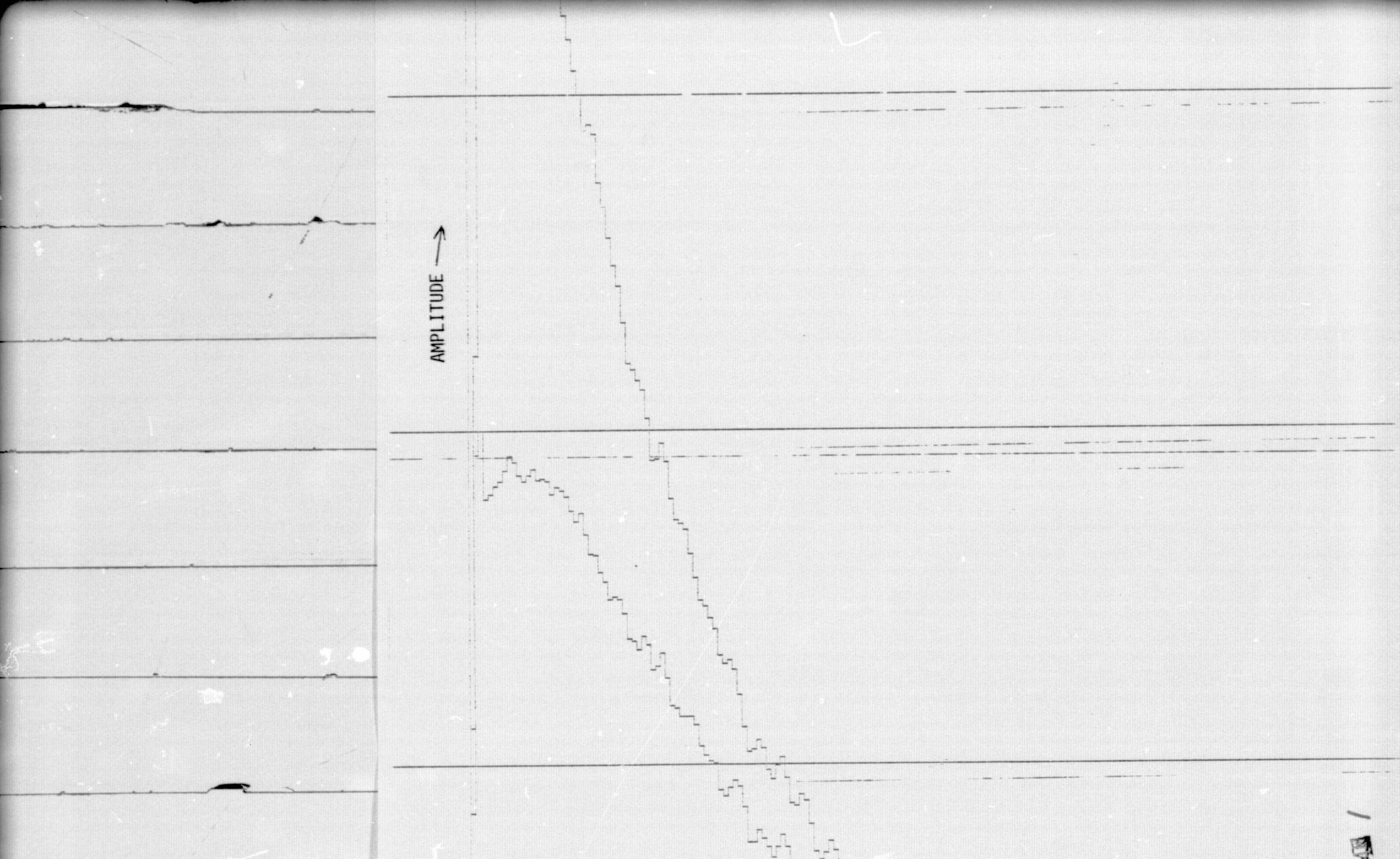
FOLDOUT FRAME

FOLDOUT FRAME 2

Program ECKPDF - Sample Printout

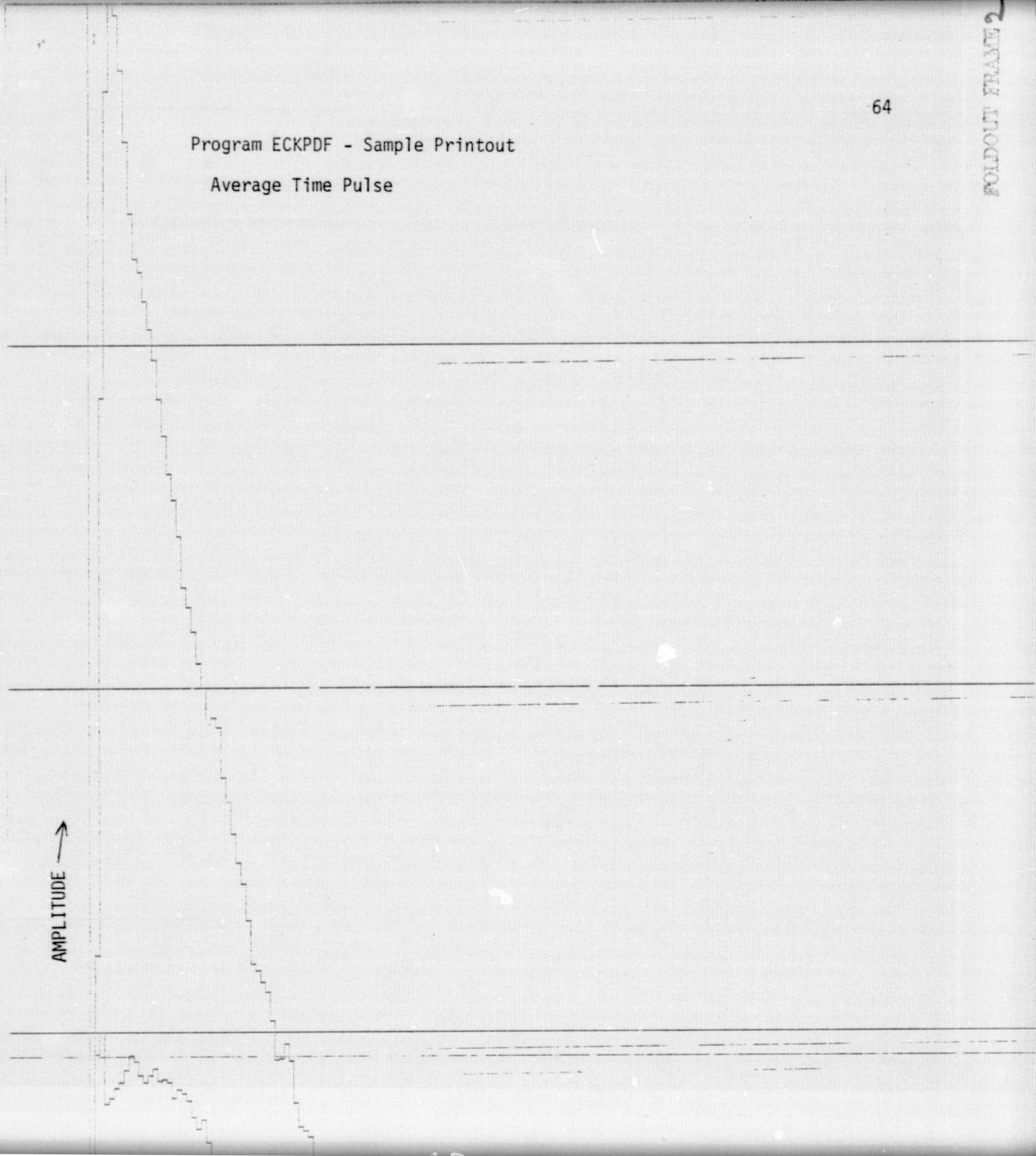
Amplitude Probabilities

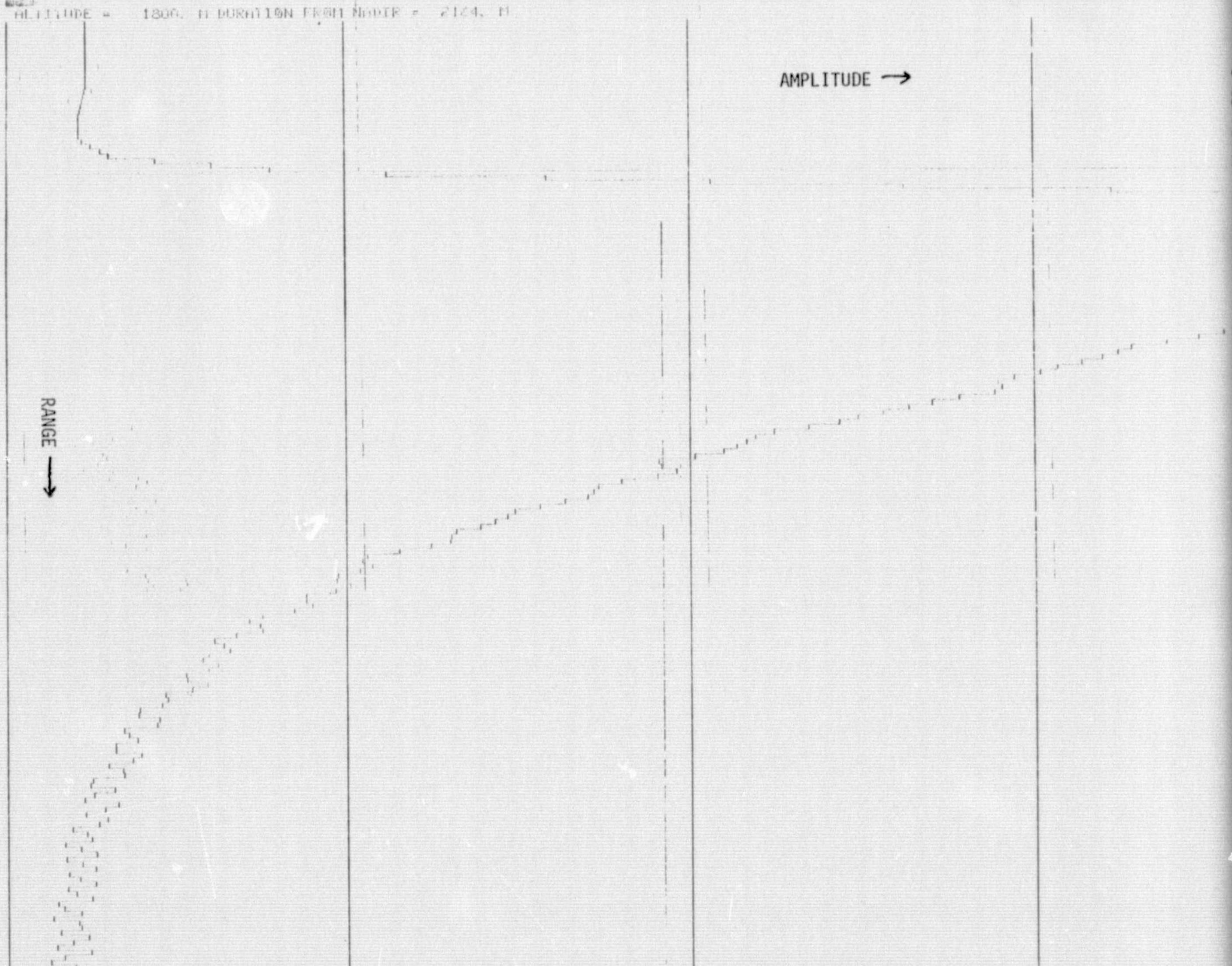



AMPLITUDE →
TIME →

Program ECKPDF - Sample Printout

Average Time Pulse

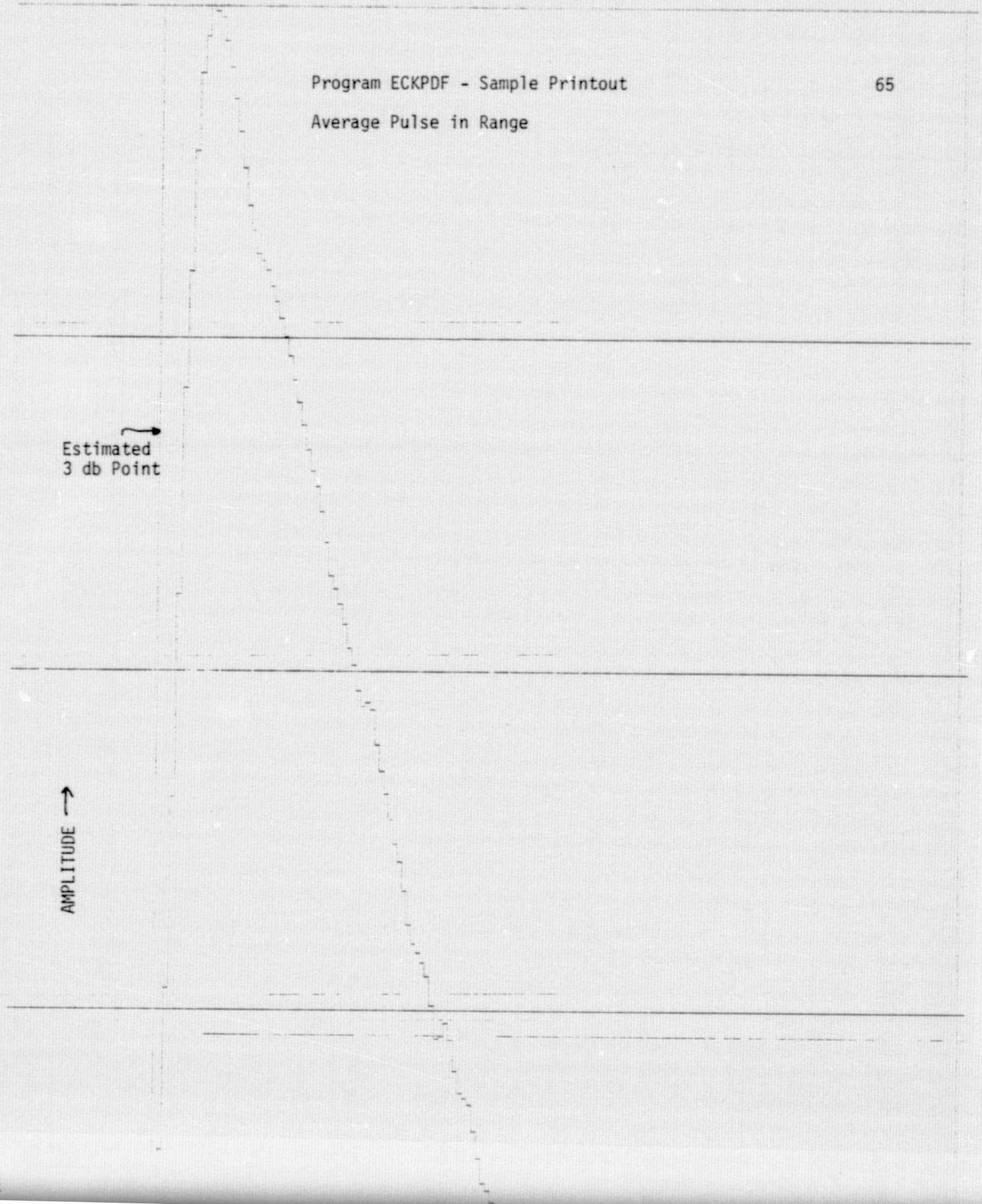


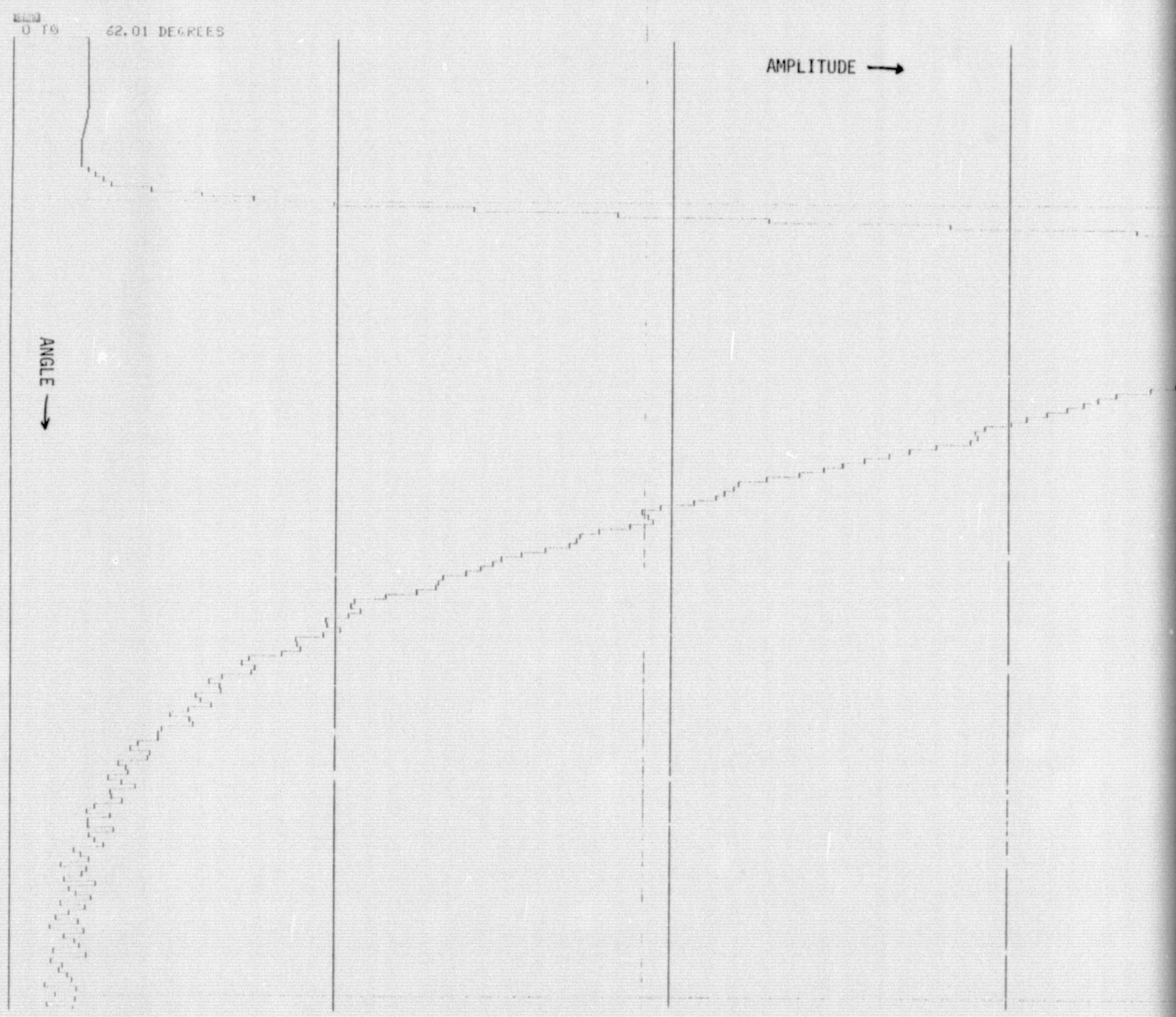


FOLDOUT FRAME 1

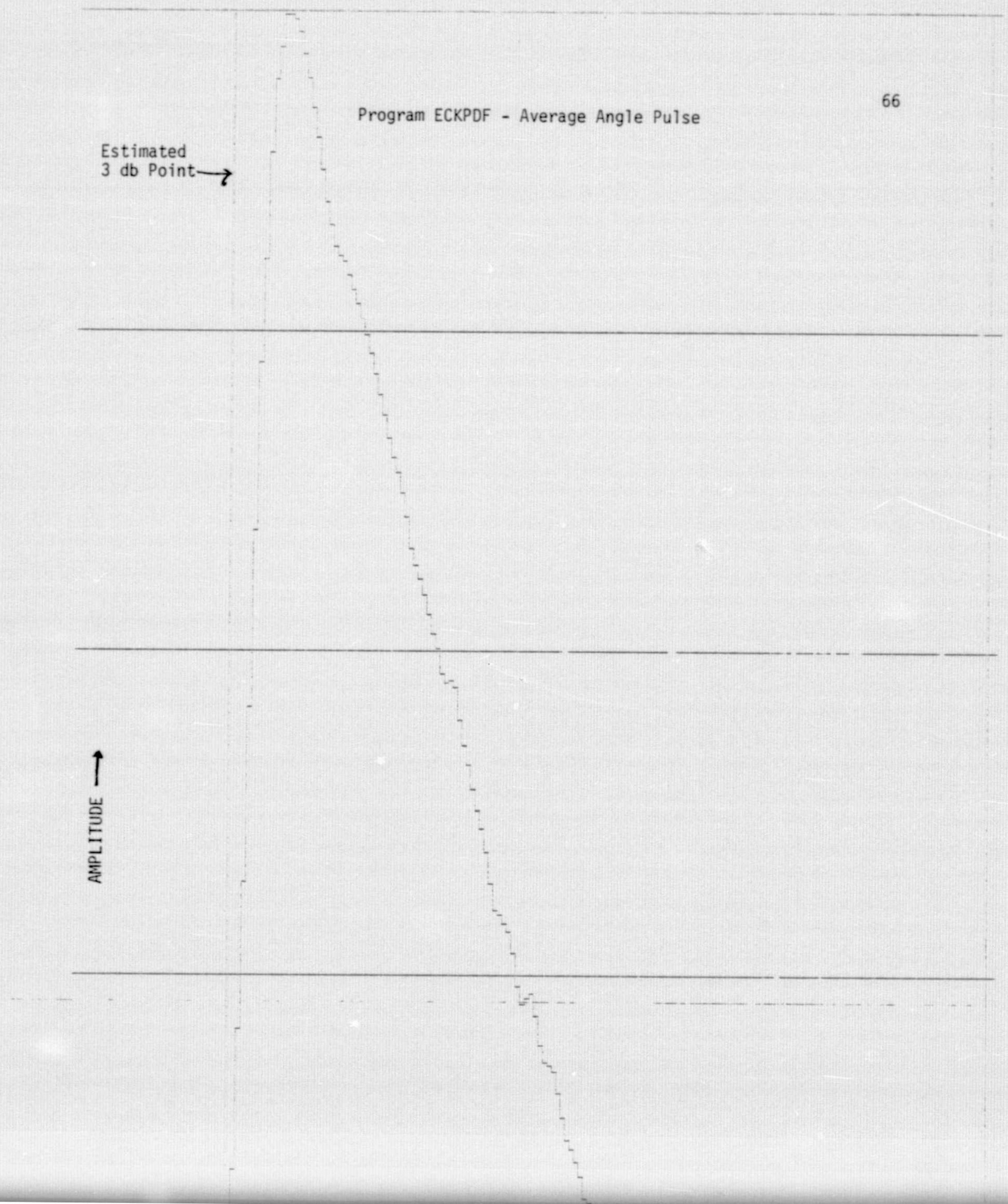
Program ECKPDF - Sample Printout 65

Average Pulse in Range





FOLDOUT FRAME

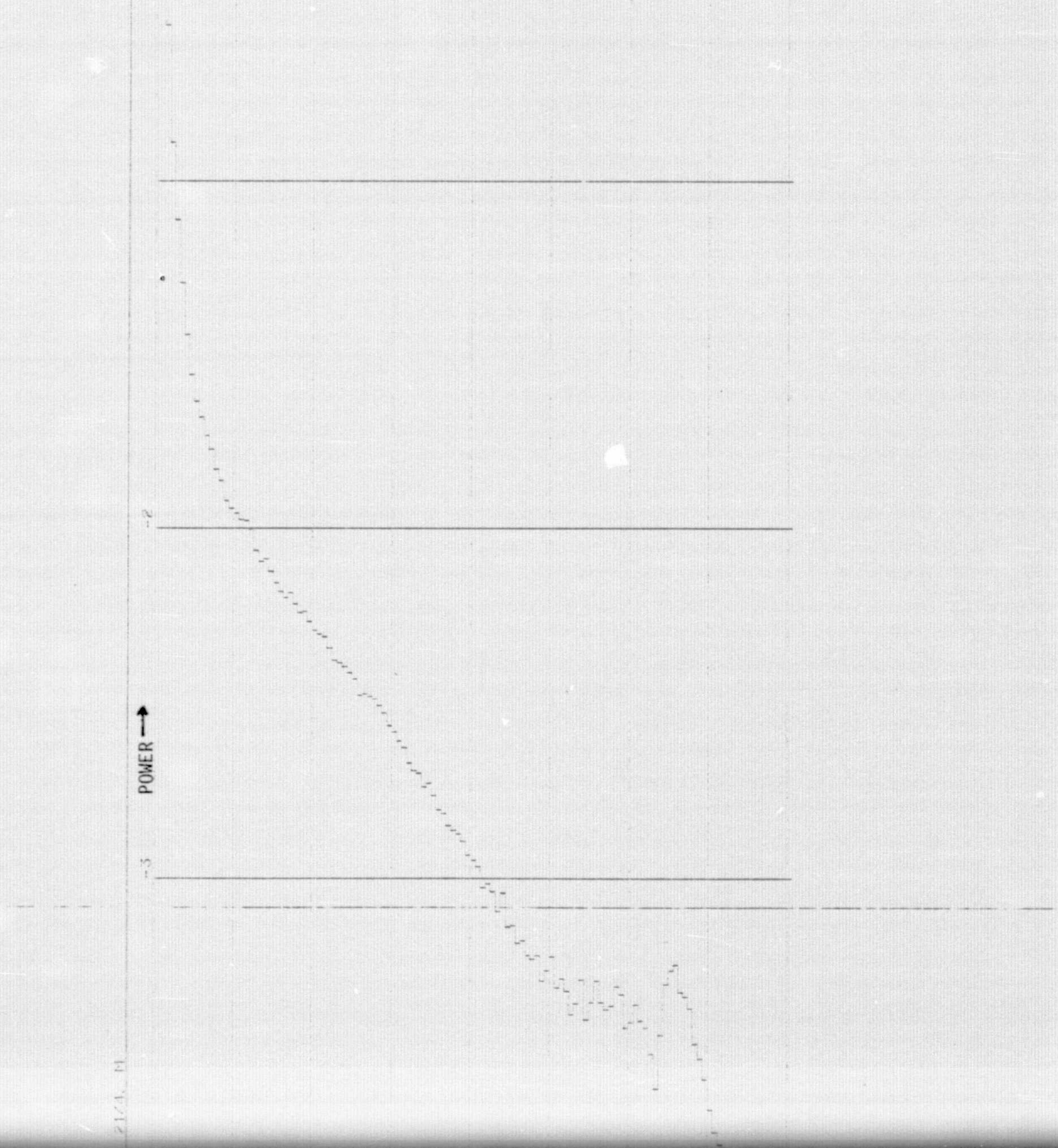

66
Program ECKPDF - Average Angle Pulse
Estimated
3 db Point
AMPLITUDE

FOLDOUT FRAME /

ORIGINAL PAGE IS OF POOR QUALITY

Program ECKPDF - Sample Printout

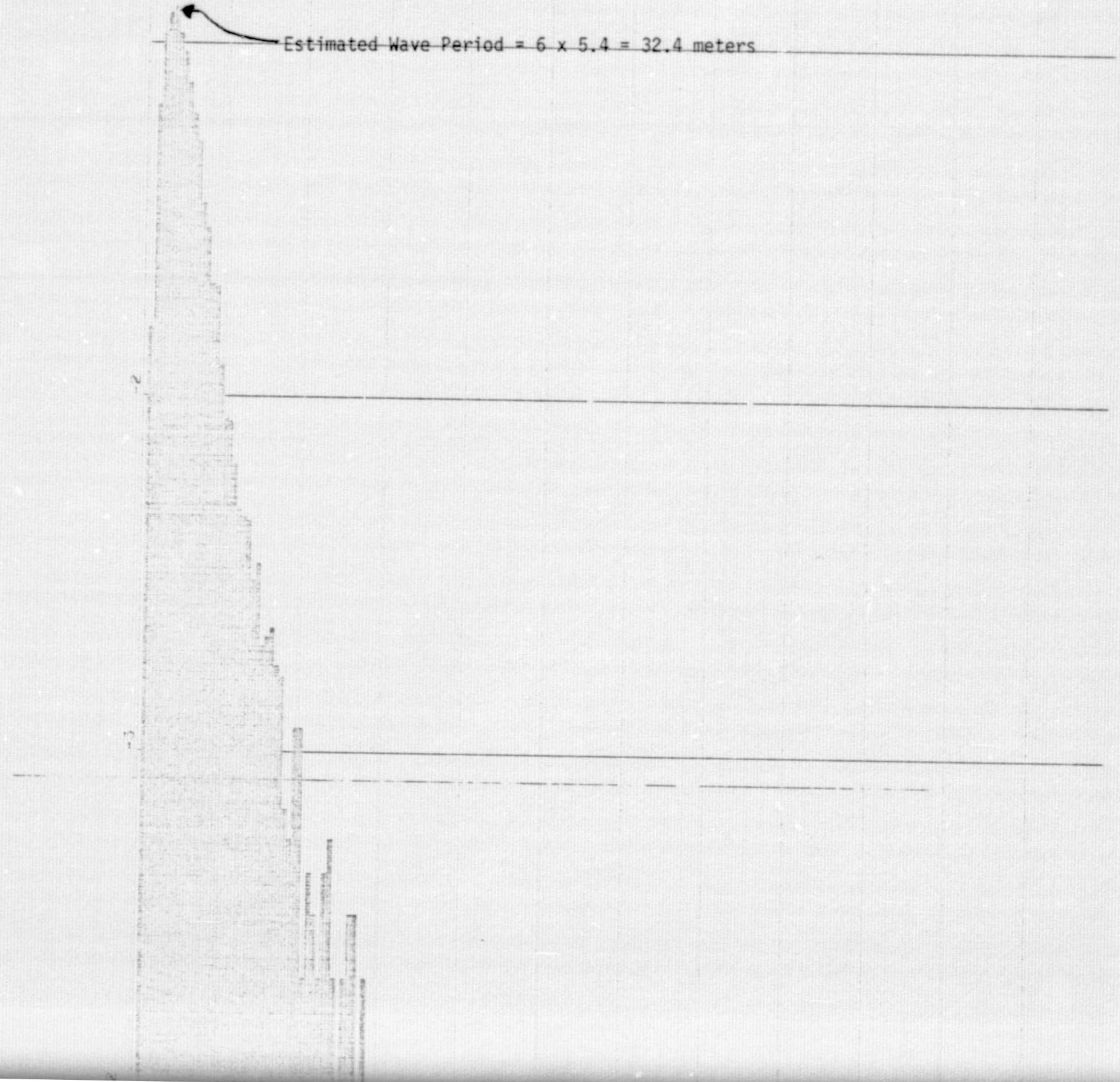
Average Power Spectrum



FOLDOUT FRAME

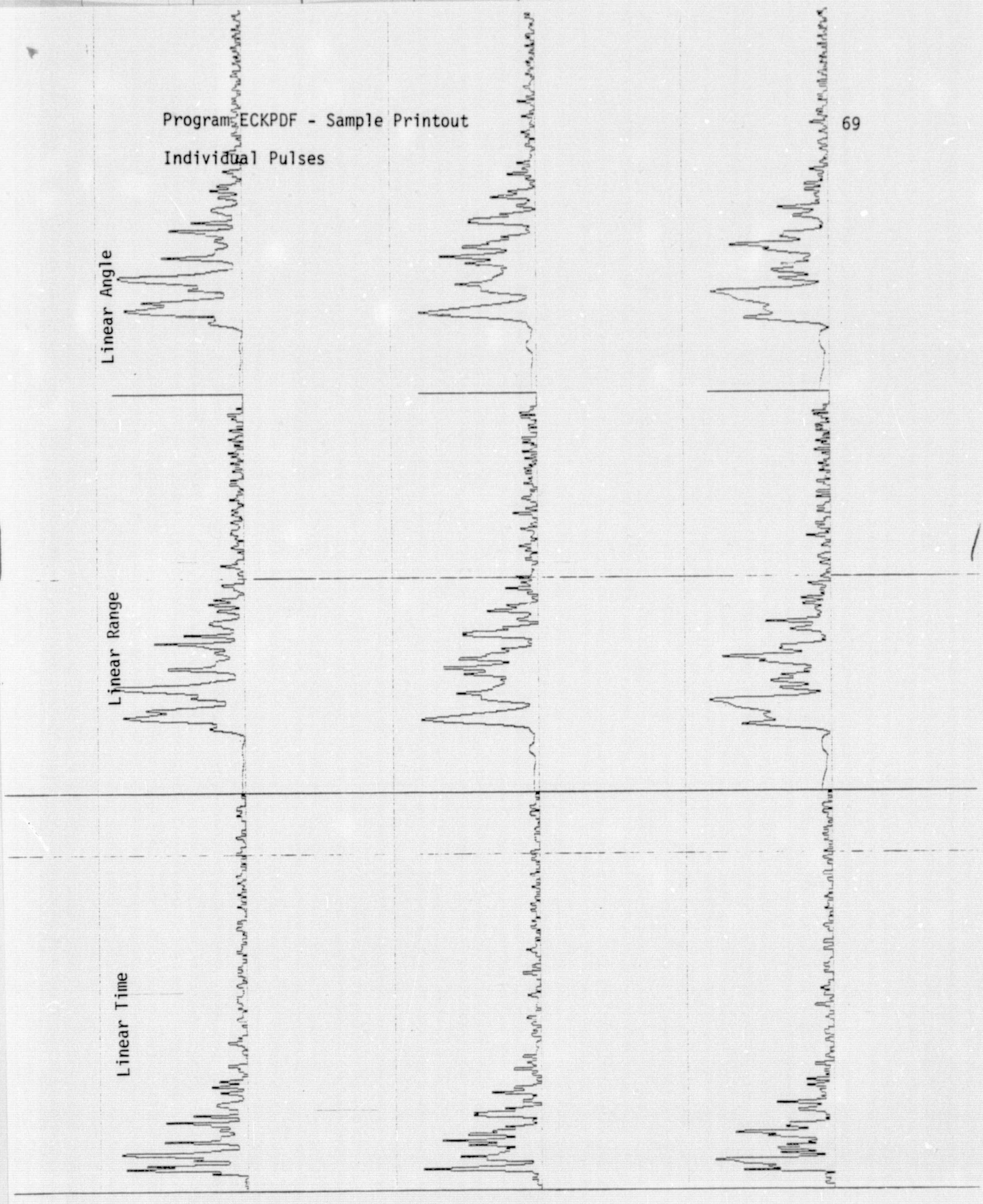
Program ECKPDF - Sample Printout

Interpeak Time Histogram



Program ECKPDF - Sample Printout

Individual Pulses



Appendix F

SHORT PULSE RADAR SIMULATION

Program Listing and Sample Printouts

Program SIMUL - Program Listing


```
$ASSM
SIMUL PRØG 2 D SHØRT PULSE SCATTER SIMULATIØN LDD 2/76
 ERLST
$FØRT
C PRØGRAM TØ SIMULATE A MØDIFICATIØN ØF EQN (4) IN THE TIME
C DØMAIN ØF "SPECTRUM ØF PØWER---" BY LEVINE ØF AUG 1974
C THE STATIØNARY PØINTS ARE FØUND FØR A GIVEN SURFACE
C USING FFT TECHNIQUES
C BØTH A SINUSØIDAL AND A GAUSSIAN SURFACE
C CØMPØNENT ARE ALLØWED. THE SURFACE
C IS GENERATED IN THE FREQUENCY DØMAIN
C TØ GET THE DESIRED SPECTRUM. THE
C RANDØM SURFACE IS PIERCE-MØSKØWITZ
C WITH GIVEN PEAK FREQUENCY AND
C RMS VALUE AS INPUT. THE SINUSØIDAL
C PART HAS THE SAME PERIØD BUT ANY
C ØTHER CHØSEN RMMS VALUE.
C PRØGRAM BY TECHNØ-SCIENCES,INC 1976
C
C
      IMPLICIT INTEGER*2 (I-N)
      INTEGER*4 IRAN
      CØMPLEX Z(1024),ZD(1024),ZDD(1024),CMPLX,CØNJG
      CØMPLEX W, ZZ
      DIMENSIØN TBL(513),IGRD(21),IPLØT(21),LAST(31)
      DIMENSIØN RANGE(1024),CRØØT(1024)
      EQUIVALENCE (RANGE(1),Z(1)),(CRØØT(1),ZDD(1))
      TAN(X)=SIN(X)/CØS(X)
C SPEC(X)=PIERSØN-MØSKØWITZ SPECTRUM
      SPEC(X)=A2*EXP(-AMIN1(130.,BG2U4/(X*X)))/(X**3)
C X=ANGULAR SURFACE FREQUENCY
C IRAN=RANDØM NUMBER GENERATØR
C GAUSSIAN PULSE SHAPE
      PULSE(X)=EXP(-((X/SIGPLS)**2)/2.)
C (SIN(X)/X)**2=ANTENNA PØWERGAIN PATTERN
      GAIN(X)=(SIN(X/ANGVAL)/AMAX1(ABS(X/ANGVAL),1.E-8))**2
      DATA SIGTIM/.006/
      DATA IRAN/1234321/
      DATA NFFT/1024/
      DATA LU/3/
      DATA P2/6.2831853/
      DATA C,DT,PULSTM,F0/300.,.00125,.01,13900./
C C=SPEED ØF LIGHT,DT=TIME INCR,PULSTM=PULSE DURATIØN
      DATA I3/3/
      DATA I4/4/
C DTØR =DEGREES TØ RADIANS CØNVERSIØN
      DATA DTØR/.01745329/
      DATA IØNE,IBIG/1,30000/
      DATA IGDPTS/7/
      W0=F0*P2
      NFFT2=NFFT/2
      NFFT21=NFFT2+1
```

```
      WRITE(0.25)
25    FØRMAT(59HENTER RMS SINUSØIDAL(M. ),
     1RMS RANDØM(P-M)(M. ),PERIØD(M. )(F8)   )
      READ(0.26) RMSSIN,RMSRAN,PERIØD
26    FØRMAT(8F8)
      WRITE(0.27)
27    FØRMAT(33HENTER RC 3DB CUTØFF*PULSE DUR(F8) )
      READ(0.26) FOTS
      WRITE(0.31)
31    FØRMAT(30HWAVE REPEATS,PULSE REPEATS(I5))
      READ(0.32) IRPTW,IRPTP
32    FØRMAT(8I5)
      WRITE(0.41)
41    FØRMAT(11HBLØCKS?(I5))
      READ(0.32) IBLKS
      RHØ=EXP(-P2*FOTS*DT/PULSTM)
      RHØ1=SQRT(1.-RHØ*RHØ)
      BG2U4=P2*P2*1.5/(PERIØD*PERIØD)
      A2=P2*RMSRAN*RMSRAN*BG2U4
      ALTUD=2000.
      C2=C/2.
C CØNVERT FRØM PULSE TIME SIGMA TØ RANGE SIGMA
      SIGPLS=SIGTIM*C2
C RNGINC=ASSUMED PULSE START,END PØINT
      RNGINC=6.*SIGPLS
      ANGLIN=18.
      ANGCTR=ANGLIN*DTØR
      BMWITH=26.
      ANG3DB=BMWITH*DTØR/2.
      ANGMAX=ANGCTR+ANG3DB
      ANGMIN=ANGCTR-ANG3DB
      ANGVAL=ANG3DB/1.39
      Y0=ALTUD*TAN(ANGMIN)
C SET UP GRID
      GDINC=1399./FLØAT(IGDPTS-1)
      DØ 5 I=1,IGDPTS
5     IGRD(I)=FLØAT(I-1)*GDINC +.5
      Y3DB=ALTUD*(TAN(ANGMAX)-TAN(ANGMIN))
      DY=Y3DB/FLØAT(NFFT)
      DY2=DY/2.
      Y02=Y0-DY2
C DF*DY=1/NFFT
      DF=1./Y3DB
      RTDF=SQRT(DF)
      DW=P2*DF
C DW=DELTA ØMEGA,DF=DELTA FREQ
C SET UP FFT TABLE
      CALL FØUR1T(2,NFFT,TBL,0)
C SET BLØCK CØUNTER TØ ZERØ BEFØRE LØØPING
      ICØUNT=0
C SET UP RANDØM PART ØF WAVE TRANSFØRM WITH SPECTRUM SPEC(X)
C DC PARTS=0
```

```
40     Z(1)=CMPLX(0.,0.)
       ZD(1)=CMPLX(0.,0.)
       ZDD(1)=CMPLX(0.,0.)
       DØ 1 I=2,NFFT21
       X=FLØAT(I-1)*DW
       Z(I)=CMPLX(SQRT(SPEC(X))*RANDG(IRAN),0.)*RTDF
1      CØNTINUE
       IFREQ=Y3DB/PERIØD+.5
C SET UP NØN-RANDØM WAVE CØMPØNENT
       Z(IFREQ)=Z(IFREQ)+CMPLX(RMSSIN/SQRT(2.),0.)
C SET UP FØR PLØT SCALE FACTØRS
       SCALE=RMSSIN**2
       X=FLØAT(IFREQ-1)*DW
       SCALE1=SCALE*X*X
       SCALE2=SCALE1*X*X
       DØ 2 I=2,NFFT21
       X=FLØAT(I-1)*DW
       XX=SPEC(X)*2.*DF
       SCALE=SCALE+XX
       XX=XX*X*X
       SCALE1=SCALE1+XX
       XX=XX*X*X
       SCALE2=SCALE2+XX
       W=CMPLX(0.,X)
       ZD(I)=W*Z(I)
       ZDD(I)=W*ZD(I)
2      CØNTINUE
       SCALE=SQRT(SCALE)
       SCALE1=SQRT(SCALE1)
       SCALE2=SQRT(SCALE2)
       DØ 3 I=2,NFFT21
       IC=NFFT+2-I
       Z(IC)=CØNJG(Z(I))
       ZD(IC)=CØNJG(ZD(I))
       ZDD(IC)=CØNJG(ZDD(I))
3      CØNTINUE
       CALL FØUR1T(Z,NFFT,TBL,IØNE)
       CALL FØUR1T(ZD,NFFT,TBL,IØNE)
       CALL FØUR1T(ZDD,NFFT,TBL,IØNE)
C FIND STATIØNARY PØINTS ASSUMING LINEAR INTERPØLATIØN
C AND PLØT Z(Y),FIRST&2D DERIVATIVES
       CALL SETGRD(LU,IGRD,IGDPTS,IBIG)
       TMDIF=(Y02+DY)/ALTUD - REAL(ZD(1))
       K=0
       DØ 4 I=1,NFFT
       Y=FLØAT(I)*DY+Y02
       TANTHT=Y/ALTUD
       TANALF=REAL(ZD(I))
       TANDIF=TANTHT-TANALF
       IF (TANDIF*TMDIF.GT.0.) GØ TØ 6
       DLT=TMDIF/(TMDIF-TANDIF)
       DLT1=1.-DLT
```

```
      Y=Y+DLT*DY
      HEIGHT=REAL(Z(I-1))*DLT1+DLT*REAL(Z(I))
      DERIV=REAL(ZD(I-1))*DLT1+DLT*TANALF
      DERIV2=REAL(ZDD(I-1))*DLT1+DLT*REAL(ZDD(I))
      K=K+1
      RANGE(K)=SQRT(Y*Y+(ALTUD-HEIGHT)**2)
      ANG=ATAN(DERIV)
      RADCRV=((1.+DERIV*DERIV)**1.5)/DERIV2
      CR00T(K)=SQRT(ABS(RADCRV/((RADCRV-RANGE(K))*RANGE(K))))
      CR00T(K)=CR00T(K)*GAIN(ANG-ANGCTR)
6     C0NTINUE
      IF(IRPTW.EQ.0)G0 T0 4
      IPL0T(1)=20.*REAL(Z(I))/SCALE+233.5
      IPL0T(2)=20.*REAL(ZD(I))/SCALE1+700.
      IPL0T(4)=20.*TANTHT/SCALE1+700.
      IPL0T(3)=20.*REAL(ZDD(I))/SCALE2+1167.5
      D0 30 J=1,IRPTW
C REPEAT T0 SPREAD SCALE
30    CALL PL0TIT(IPL0T,LAST,I4,I0NE)
4     TMDIF=TANDIF
      NUM=K
C RE0RDER IN INCREASING RANGE
10    D0 7 K=2,NUM
      IF(RANGE(K-1).GT.RANGE(K)) G0 T0 8
7     C0NTINUE
      G0 T0 9
8     X=RANGE(K)
      RANGE(K)=RANGE(K-1)
      RANGE(K-1)=X
      X=CR00T(K)
      CR00T(K)=CR00T(K-1)
      CR00T(K-1)=X
      G0 T0 10
9     C0NTINUE
C GENERATE 0UTPUTS N0W
      TIME=(RANGE(1)-RNGINC)/C2
      Y=0.
      LAST(1)=0
      IPL0T(1)=0
      WRITE(3,21)
21    F0RMAT(1H0)
11    TIME=TIME+DT
      RG=C2*TIME
C RG=RANGE F0R PULSE CENTER
C RGMAX,RGMIN=START END
      RGMAX=RG+RNGINC
     .RGMIN=RG-RNGINC
C FIND REFLECT0R LIMITS,MINV,MAXV
C I.E. TH0SE IN THE RANGE BIN
      D0 12 I=1,NUM
      IF(RANGE(I).GE.RGMIN) G0 T0 13
12    C0NTINUE
```

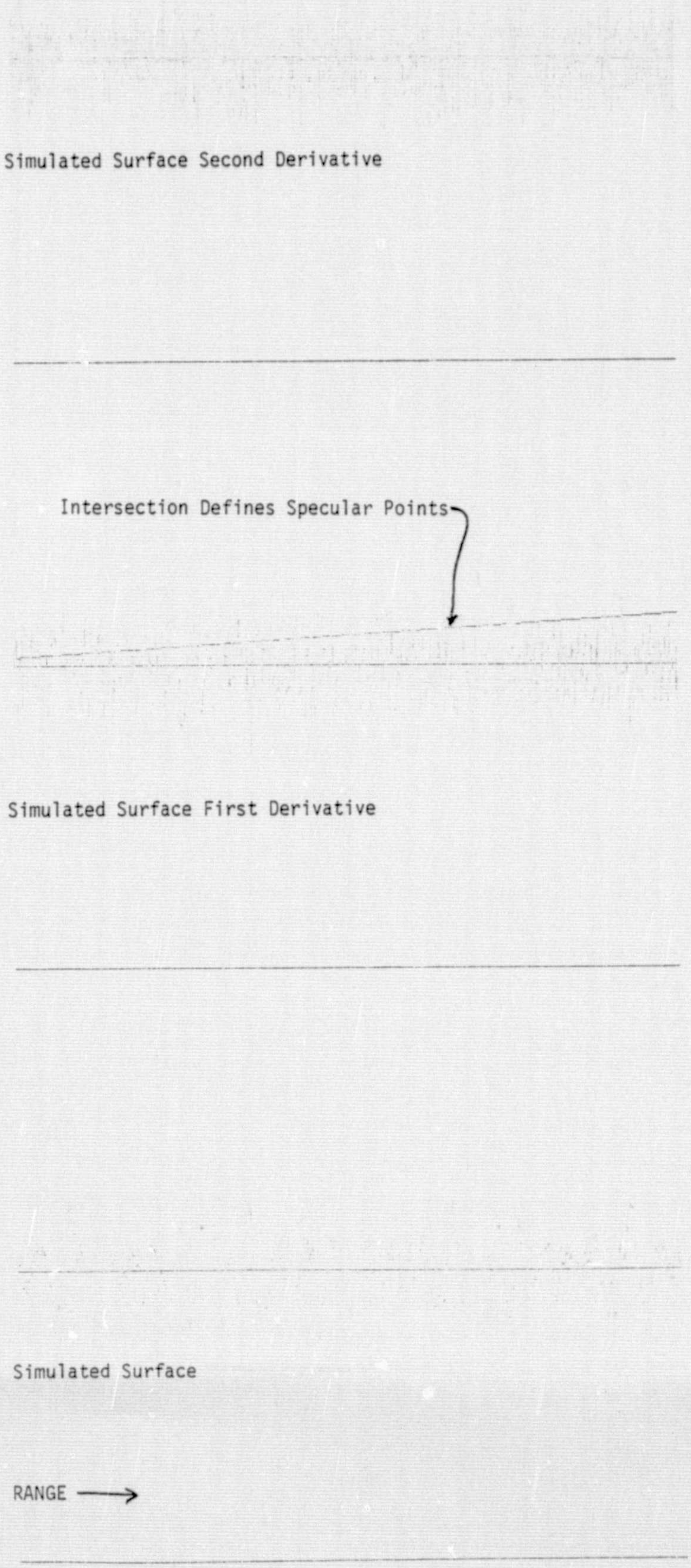
```
      ICØUNT=ICØUNT+1
      IF(ICØUNT.LT.IBLKS) GØ TØ 40
      STØP
13    MINV=I
      DØ 14 I=MINV,NUM
      IF(RANGE(I).GT.RGMAX) GØ TØ 15
14    CØNTINUE
      I=NUM+1
15    MAXV=I-1
      ZZ=CMPLX(0.,0.)
C GENERATE ØUTPUTS
C & PLØT THEM
      IF(MAXV.LT.MINV)GØ TØ 20
      DØ 16 I=MINV,MAXV
      ANG=WO*(RANGE(I)-RANGE(MINV))/C2
      W=CMPLX(CØS(ANG),SIN(ANG))
      ZZ=ZZ+CRØØT(I)*PULSE(RANGE(I)-RG)*W
16    CØNTINUE
C FILTER
20    X=RHØ*Y+RHØ1*(CABS(ZZ)**2)
      Y=X
      IF(IRPTP.EQ.0)GØ'TØ 11
      IPLØT(1)=1400.*X*ALTUD
      DØ 24 I=1,IRPTP
24    CALL PLØTIT(IPLØT,LAST,IØNE,IØNE)
18    FØRMAT(1H ,4E18.6,4I7)
      GØ TØ 11
      END
.U        EXT FUNC
IRAN      INT4 VAR
Z         CMPX VAR
ZD        CMPX VAR
ZDD       CMPX VAR
CMPLX     EXT FUNC
CØNJG     EXT FUNC
W         CMPX VAR
ZZ        CMPX VAR
TBL       REAL VAR
IGRD      INT2 VAR
IPLØT     INT2 VAR
LAST      INT2 VAR
RANGE     REAL VAR
CRØØT     REAL VAR
TAN       STATE FN
.Q        EXT FUNC
.P        EXT FUNC
X[illegible]  FØRM PAR
SIN       EXT FUNC
CØS       EXT FUNC
SPEC      STATE FN
X[illegible]  FØRM PAR
A2        REAL VAR
```

```
EXP       EXT FUNC
AMIN1     EXT FUNC
BG2U4     REAL VAR
.R        EXT FUNC
PULSE     STATE FN
X█        FØRM PAR
SIGPLS    REAL VAR
GAIN      STATE FN
X█        FØRM PAR
ANGVAL    REAL VAR
AMAX1     EXT FUNC
ABS       EXT FUNC
SIGTIM    REAL VAR
NFFT      INT2 VAR
LU        INT2 VAR
F2        REAL VAR
C         REAL VAR
DT        REAL VAR
PULSTM    REAL VAR
F0        REAL VAR
I3        INT2 VAR
I4        INT2 VAR
DTØR      REAL VAR
IØNE      INT2 VAR
IBIG      INT2 VAR
IGDPTS    INT2 VAR
W0        REAL VAR
NFFT2     INT2 VAR
NFFT21    INT2 VAR
25        LABEL
@H        EXT FUNC
26        LABEL
RMSSIN    REAL VAR
RMSRAN    REAL VAR
PERIØD    REAL VAR
27        LABEL
FOTS      REAL VAR
31        LABEL
32        LABEL
IRPTW     INT2 VAR
IRPTP     INT2 VAR
41        LABEL
IBLKS     INT2 VAR
RHØ       REAL VAR
RHØ1      REAL VAR
SQRT      EXT FUNC
ALTUD     REAL VAR
C2        REAL VAR
RNGINC    REAL VAR
ANGLIN    REAL VAR
ANGCTR    REAL VAR
BMWITH    REAL VAR
```

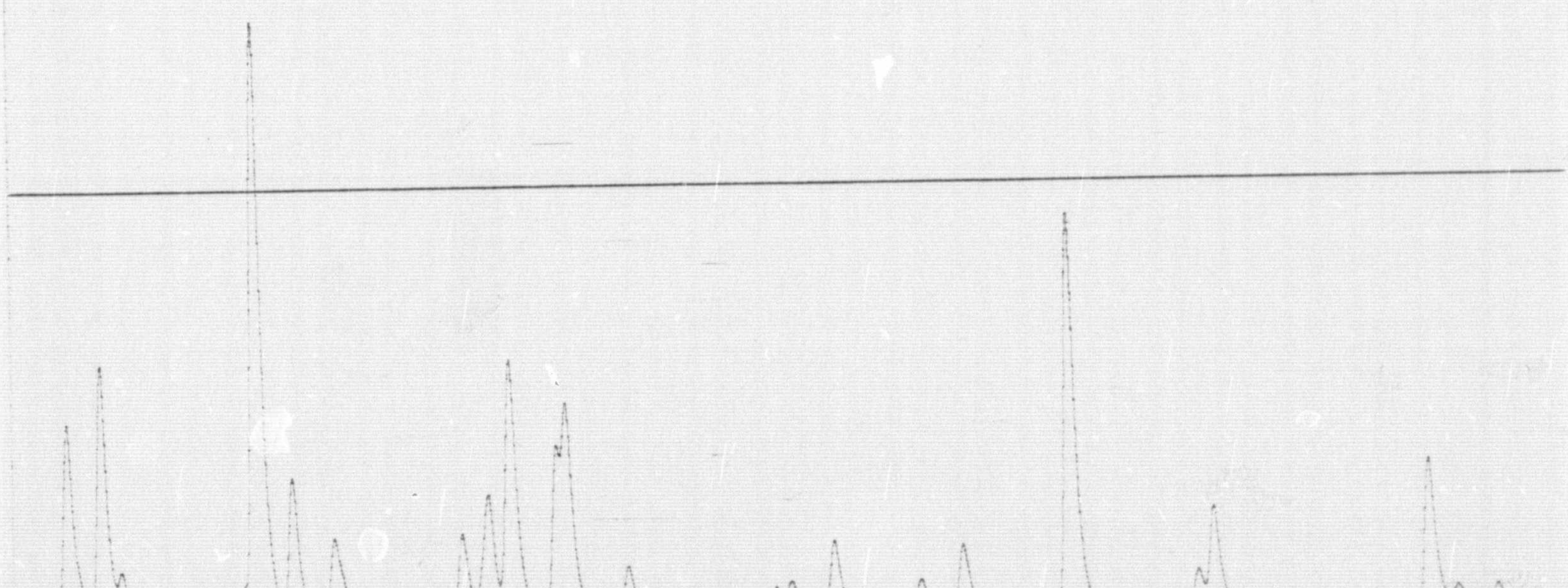
```
ANG3DB   REAL VAR
ANGMAX   REAL VAR
ANGMIN   REAL VAR
YO       REAL VAR
GDINC    REAL VAR
FLØAT    EXT FUNC
FLØAT2   EXT FUNC
5        LABEL
I        INT2 VAR
.Y       EXT FUNC
Y3DB     REAL VAR
DY       REAL VAR
DY2      REAL VAR
YO2      REAL VAR
DF       REAL VAR
RTDF     REAL VAR
DW       REAL VAR
FØUR1T   EXT FUNC
ICØUNT   INT2 VAR
40       LABEL
$P       EXT FUNC
1        LABEL
X        REAL VAR
RANDG    EXT FUNC
$M       EXT FUNC
IFREQ    INT2 VAR
$L       EXT FUNC
$A       EXT FUNC
SCALE    REAL VAR
SCALE1   REAL VAR
SCALE2   REAL VAR
2        LABEL
XX       REAL VAR
$K       EXT FUNC
3        LABEL
IC       INT2 VAR
SETGRD   EXT FUNC
TMDIF    REAL VAR
REAL     EXT FUNC
K        INT2 VAR
4        LABEL
Y        REAL VAR
TANTHT   REAL VAR
TANALF   REAL VAR
TANDIF   REAL VAR
6        LABEL
DLT      REAL VAR
DLT1     REAL VAR
HEIGHT   REAL VAR
DERIV    REAL VAR
DERIV2   REAL VAR
ANG      REAL VAR
```

```
ATAN     EXT FUNC
RADCRV   REAL VAR
.A       EXT FUNC
30       LABEL
J        INT2 VAR
PLØTIT   EXT FUNC
NUM      INT2 VAR
10       LABEL
7        LABEL
8        LABEL
9        LABEL
TIME     REAL VAR
21       LABEL
11       LABEL
RG       REAL VAR
RGMAX    REAL VAR
RGMIN    REAL VAR
12       LABEL
13       LABEL
.S       EXT FUNC
MINV     INT2 VAR
14       LABEL
15       LABEL
MAXV     INT2 VAR
20       LABEL
16       LABEL
CABS     EXT FUNC
24       LABEL
18       LABEL
.V       EXT FUNC

0000 ERRØRS
```

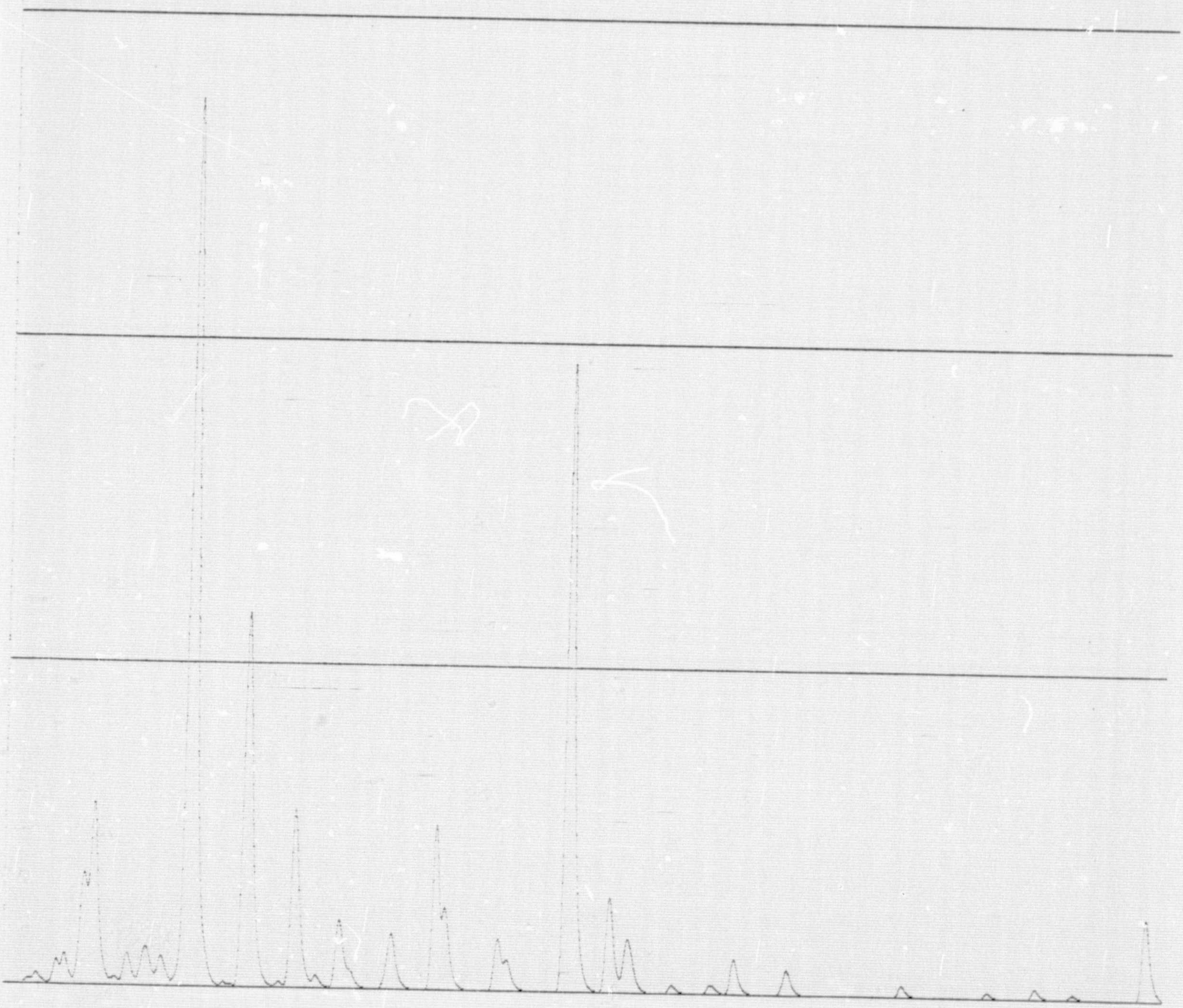
Program SIMUL - Sample Printout



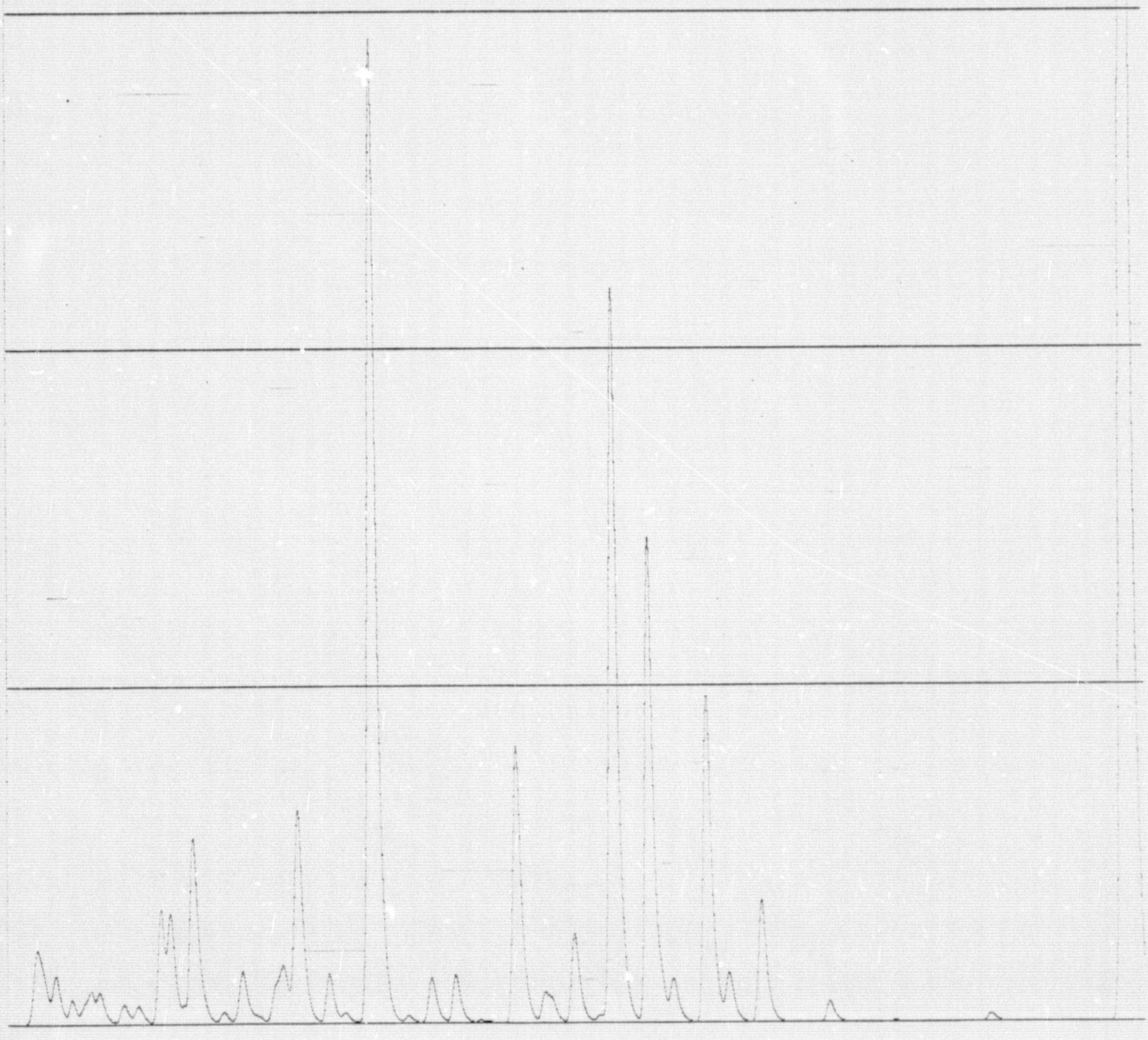
Program SIMUL - Sample Pulse



Program SIMUL - Sample Pulse



Program SIMUL Sample Pulse



Appendix G

SUBROUTINES

Program Listings

Program PLOTIT

PRØG= PLØTIT X 03-066R03M31

```
                                        SCRAT
                             * ENTRIES AT SETGRD AND PLØTIT
                             * FØRTRAN CALLABLE. SETGRD MUST BE CALLED
                             * FIRST TØ SET UP GRID PLØTTING. CALL IS:
                             *       CALL SETGRD(LU,IGRID(1),NGRID,NXSPACE)
                             * WHERE:
                             * LU=PLØTTER L.U.
                             * IGRID IS AN ARRAY ØF Y GRID LØCATIØNS
                             * NGRID=THE NUMBER ØF THESE PØINTS
                             * NXSPACE=NUMBER ØF PØINTS BETWEEN GRID
                             * LINES IN THE X-DIRECTIØN. IF =0,NØ GRID LINES
                             * TØ PLØT.CALL
                             *       CALL PLØTIT(IDATA,LASTDATA,NPØINTS,NCØNNECT)
                             * WHERE IDATA IS A DATA ARRAY
                             * NCØNNECT= 0 TØ PLØT PØINTS ØNLY.
                             * NE TØ CØNNECT THE PRESENT PØINT WITH
                      X      * THE LAST. IF .LT.0,CØNNECT FRØM 0(BAR TYPE).
                             * NPØINTS=NUMBER ØF PØINTS IN DATA ARRAY
                             * LASTDATA IS AN ARRAY TØ HØLD THE LAST
                             * PØINTS ØF DIMENSIØN EQUAL TØ NPØINTS.
                             * LASTDATA IS USED EVEN IF NØ CØNNECTIØN
                             * IS DESIRED, AND MUST BE GIVEN.
                             * ALL VALUES ARE 2-BYTE INTEGERS.
                             * AND ARE ASSUMED TØ LIE BETWEEN 0 &
                             * MAXPTS-1=1399. THEY ARE LIMITED TØ
                             * THIS RANGE IF THEY ARE NØT ØN ENTRY.
                             *
 000000I                                ENTRY   SETGRD,PLØTIT
 000000I                                EXTRN   .0
                             *
 000000I   D0A0 8168         SETGRD     STM     10,REG              SAVE REGS
 000004I   48EF 0000                    LH      14,0(15)            GET NUMB ØF 2*(ARGS+1)
 000008I   C4F0 FFFC                    NHI     15,X'FFFC'          MASK 15 TØ F.W.
 00000CI   50F0 8170                    ST      15,R15              & SAVE
 000010I   27EA                         SIS     14,10               NØW CK ARGS
 000012I   2337                         BZS     ØKS
 000014I   C8B0 3333         ERR        LHI     11,C'33'
 000018I   41F0 4000 0000F              BAL     15,.0               SEND ERR MESS
 00001EI   E130                         DCX     E130                & QUIT
 000020I   24E0              ØKS        LIS     14,0                SET UP GRID ARRAY
 000022I   25C1                         LCS     12,1
 000024I   C8D0 00AC                    LHI     13,LINESIZE-3
 000028I   50ED 8210         P1         ST      14,GØUT(13)         ZERØ THIS ØNE
 00002CI   50CD 815C                    ST      12,GRID(13)         ALL ØNES FØR VERTICAL LINE
 000030I   27D4                         SIS     13,4                DECR CNT
 000032I   2215                         BNMS    P1
 000034I   D1CF 0004                    LM      12,4(15)            GET ARGS
 000038I   48CC 0000                    LH      12,0(12)            SET LU
 00003CI   D2C0 8105                    STB     12,WRITE+1
 000040I   D2C0 8115                    STB     12,WRGRID+1
 000044I   48EE 0000                    LH      14,0(14)            GET NUMBER ØF GRID LINES
 000048I   11E1                         SLLS    14,1                *2 FØR ACCESS
 00004AI   27E2              P2         SIS     14,2                DECR PTR
*00004CI   211E                         BM      P3                  QUIT WHEN -
 00004EI   48CD 4E00 0000               LH      12,0(13,14)         GET NEXT PØINT
 000054I   2312                         BNMS    P4                  CK LIMITS
 000056I   24C0                         LIS     12,0                SET=0
 000058I   C5C0 0578         P4         CLHI    12,MAXPTS           CK TØØ LARGE
 00005CI   2183                         BLS     P5
 00005EI   C8C0 0577                    LHI     12,MAXPTS-1         LIMIT UPPER
 000062I   75C0 81D6         P5         SBT     12,GØUT             SET GRID PØINT
*000066I   220E                         B       P2                  GET NEXT
 000068I   48FF 0000         P3         LH      15,0(15)            GET X SPACES
 00006CI   50F0 8114                    ST      15,NXSPACE
 000070I   27F1                         SIS     15,1                FØRCE AXIS AT BEGINNING
 000072I   50F0 8112                    ST      15,XCØUNT
 000076I   4300 80C0                    B       P13                 EXIT
                             *
                             *
                             * PLØTTING ENTRY PØINT
 00007AI   D0A0 80EE         PLØTIT     STM     10,REG
 00007EI   48EF 0000                    LH      14,0(15)            GET ARGS
 000082I   C4F0 FFFC                    NHI     15,X'FFFC'          FIX UP R15
 000086I   50F0 80F6                    ST      15,R15
 00008AI   27EA                         SIS     14,10               CK NUMBE ARGS
 00008CI   4230 FF84                    BNZ     ERR                 IF NØN ZER,EXIT ØN ERR MESS
 000090I   D1CF 0004                    LM      12,4(15)            GET ARG LIST
 000094I   48FF 0000                    LH      15,0(15)            CØNNECT VALUE
 000098I   48EE 0000                    LH      14,0(14)            NUMBER ØF PØINTS
 00009CI   11E1                         SLLS    14,1                * 2 FØR ENTRY
 00009EI   58B0 80E6                    L       11,XCØUNT           CK FØR X GRID LINE TIME
 0000A2I   26B1                         AIS     11,1
 0000A4I   50B0 80E0                    ST      11,XCØUNT
 0000A8I   55B0 80D8                    CL      11,NXSPACE
 0000ACI   4230 801E                    BNE     P14
 0000B0I   24B0                         LIS     11,0                RESET CØUNT
 0000B2I   50B0 80D2                    ST      11,XCØUNT
 0000B6I   E110 809E                    SVC     1,WRGRID            WRITE VERTICAL LINE
 0000BAI   27E2              P16        SIS     14,2                NØW MØVE TØ LAST DATA
 0000BCI   4210 807A                    BM      P13                 UNTIL DØNE
 0000C0I   48BC 4E00 0000               LH      11,0(12,14)
```

```
 0000C6I   40BD 4E00 0000                STH     11.0(13.14)
*0000CCI   2209                          B       P16
 0000CEI   C8B0 00AC           P14       LHI     11.LINESIZE-3         SET UP ØUTPUT BUFF
 0000D2I   52AB 8166           P15       L       10.GØUT(11)           WITH GRID LINES
 0000D6I   50AB 8212                     ST      10.ØUT(11)
 0000DAI   27B4                          SIS     11.4                  DECR CØUNT
 0000DCI   2215                          BNMS    P15
 0000DEI   27E2                P6        SIS     14.2                  NØW DØ DATA PØINTS
 0000E0I   4210 8052                     BM      P7                    UNTIL DØNE
 0000E4I   48BC 4E00 0000                LH      11.0(12.14)           GET PØINT
 0000EAI   2312                          BNMS    P8                    CK LIMITS
 0000ECI   24B0                          LIS     11.0                  LIMIT TØ 0 TØ
 0000EEI   C5B0 0578           P8        CLHI    11.MAXPTS
 0000F2I   2183                          BLS     P9
 0000F4I   C8B0 0577                     LHI     11.MAXPTS-1           MAXPTS-1
 0000F3I   08FF                P9        LR      15.15                 CK FØR CØNNECT
 0000FAI   2125                        X BPS     CØNNECT               NØ MEANS CØNNECT
 0000FCI   2118                          BMS     BAR                   IF -.FØRCE 0 CØNNECT(BAR TYPE)
 0000FEI   40BD 4E00 0000                STH     11.0(13.14)           ELSE FØRCE NØ CØNNECT BY STØRE
 000104I   48AD 4EC0 0000      CØNNECT   LH      10.0(13.14)           GET LAST PØINT
 00010AI   2312                          BNMS    P10                   CK LIMITS
 00010CI   24A0                BAR ✗     LIS     10.0
 00010EI   C5A0 0578           P10       CLHI    10.MAXPTS
 000112I   2133                          BLS     P11
 000114I   C8A0 0577                     LHI     10.MAXPTS-1
 000118I   408D 4E00 0000      P11       STH     11.0(13.14)           STØRE NEW PØINT IN LAST
 00011EI   05BA                          CLR     11.10                 FØRCE (10) LT (11)
 000120I   2384                          BNLS    P12
 000122I   08FA                          LR      15.10                 MØVE
 000124I   08AB                          LR      10.11
 000126I   08BF                          LR      11.15
 000128I   75A0 81C0           P12       SBT     10.ØUT                SET BITS
 00012CI   26A1                          AIS     10.1                  UNTIL
 00012EI   05BA                          CLR     11.10                 (10)=(11)
 000130I   2234                          BNLS    P12
 000132I   4300 FFA8                     B       P6                    GET NEXT
 000136I   E110 80CA           P7        SVC     1.WRITE               WRITE IT ØUT
 00013AI   D1A0 802E           P13       LM      10.REG                EXIT
 00013EI   430F 0014                     B       20(15)
                               *
           0000 00AF           LINESIZE  EQU     175                   BYTES
           0000 0578           MAXPTS    EQU     1400                  BITS
 000144I                                 ALIGN   4
 000144I   2100                WRITE     DCX     2100.0
 000146I   0000
 000148I   0000 02ECI                    DAC     ØUT.ØUT+LINESIZE-1.0.0
 00014CI   0000 039AI
 000150I   0000 0000
 000154I   0000 0000
 000158I   2100                WRGRID    DCX     2100.0
 00015AI   0000
 00015CI   0000 018CI                    DAC     GRID.GRID+LINESIZE-1.0.0
 000160I   0000 023AI
 000164I   0000 0000
 000168I   0000 0000
 00016CI                       REG       DS      20
 000180I                       R15       DS      4
 000184I                       NXSPACE   DS      4
 000188I                       XCØUNT    DS      4
 00018CI                       GRID      DS      LINESIZE+1
 00023CI                       GØUT      DS      LINESIZE+1
 0002ECI                       ØUT       DS      LINESIZE+1
 00039CI                                 END
```

```
PRØGRAM TØ PLØT DATA LDD 1/76                                PAGE   3
NØ ERRØRS    3 SQUEZ PASSES
CALRO3
> .Ø          0000  001AI          38
  ABSTØP      0000  000G
  ADC         0000  0004
  BAR         0000  010CI         109
  CØNNECT     0000  0104I         108
  ERR         0000  0014I          76
  GØUT        0000  023CI          43    61    95
  GRID        0000  018CI          44   138   138
  IMPTØP      0000  039CI
  LADC        0000  0002
  LINESIZE    0000  00AF           42    94   136   138   143   144   145
  MAXPTS      0000  0578           58    60   104   106   114   115
  NXSPACE     0000  0184I          64    84
  ØKS         0000  0020I          36
  ØUT         0000  02ECI          96   123   136   136
  P1          0000  0028I          46
  P10         0000  010EI         112
  P11         0000  0118I         115
  P12         0000  0128I         119   126
  P13         0000  013AI          67    90
  P14         0000  00CEI          85
  P15         0000  00D2I          98
  P16         0000  00BAI          93
  P2          0000  004AI          62
  P3          0000  0068I          54
  P4          0000  0058I          56
  P5          0000  0062I          59
  P6          0000  00DEI         127
  P7          0000  0136I         100
  P8          0000  00EEI         102
  P9          0000  00F2I         105
< PLØTIT      0000  007AI
  PUFETØP     0000  000P
  R15         0000  0180I          34    74
  REG         0000  016CI          31    71   123
< SETGRD      0000  0000I
  WRGRID      0000  0158I          50    88
  WRITE       0000  0144I          49   128
  XCØUNT      0000  0182I          66    81    83    37
```

Program RANDG


```
$ASSM
RANDG PRØG GAUSSIAN RANDØM NUMBER GENERATØR LDD 3/76
 ERLST
$FØRT
      FUNCTIØN RANDG(IY)
C IY IS AN INITIALIZING VALUE,ØDD,LT 9 DIGITS,
C INTEGER*4.  NØRMAL NUMBERS GENERATED BY SUMMING
C 12 UNIFØRMS IN THE USUAL FASHIØN.  RANDU RØUTINE
C IS USED (NØT CALLED).
C
      X=0.
      DØ 1 I=1,12
      IY=IY*65539
      IF(IY.GT.0)GØ TØ 2
      IY=IY+2147483647+1
2     X=X+FLØAT(IY)
1     CØNTINUE
      RANDG=X/2147483647. - 6.
      RETURN
      END
RANDG    FUNC/SUB
RANDG    FUNC VAR
.Q       EXT FUNC
.P       EXT FUNC
IY       FØRM PAR
X        REAL VAR
1        LABEL
I        INT4 VAR
2        LABEL
FLØAT    EXT FUNC

0000 ERRØRS
```

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C.2